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# THE USE OF IODIZED RAPE-SEED OIL (CAMPIODOL) FOR RÖNTGENOGRAPHIC EXPLORATION *

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of Philadelphia, Pa.

From the Department of Surgery and the Laboratory of Research Surgery, University of Pennsylvania

Those of us living and practicing during the latter part of the nineteenth century witnessed the rapid progress of general surgery. We were privileged to observe the results of the development of cellular pathology, of bacteriological technic, and the transition from antiseptic to aseptic surgery. Without the contributions of Virchow, Pasteur, Koch, and Lister, we would still be practicing the surgery of the eighteenth century. With the progress of surgical technic, there slowly developed modern methods of precision in diagnosis. The great surgeons of the last century were known for their "surgical skill", "surgical instinct", and their "surgical touch". These watchwords have done much to retard surgical progress. Medicine, as a whole, has been slow to accept instruments of precision. The stethoscope and the clinical thermometer were early examples. Even when Röntgen demonstrated the value of the X-ray, and for years afterward, surgeons were loath to depend upon its use and were more tempted to elicit crepitation of the fragments after fracture. With the more general acceptance of the use of the X-ray in diagnosis, we have observed the exploration of the intestinal tract, of the kidney pelvis, of


Fig. 1.—Spinal subarachnoid space of a dog after cisternal injection of one and one-half cubic centimetres of campiodol.

* Read before the Philadelphia Academy of Surgery, March 4, 1929.

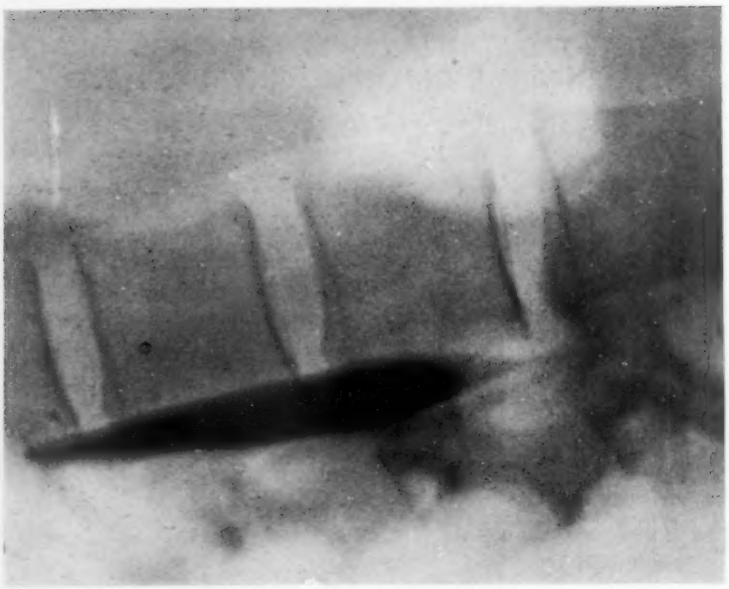

FIG. 3.—Spinal block. Lateral view.

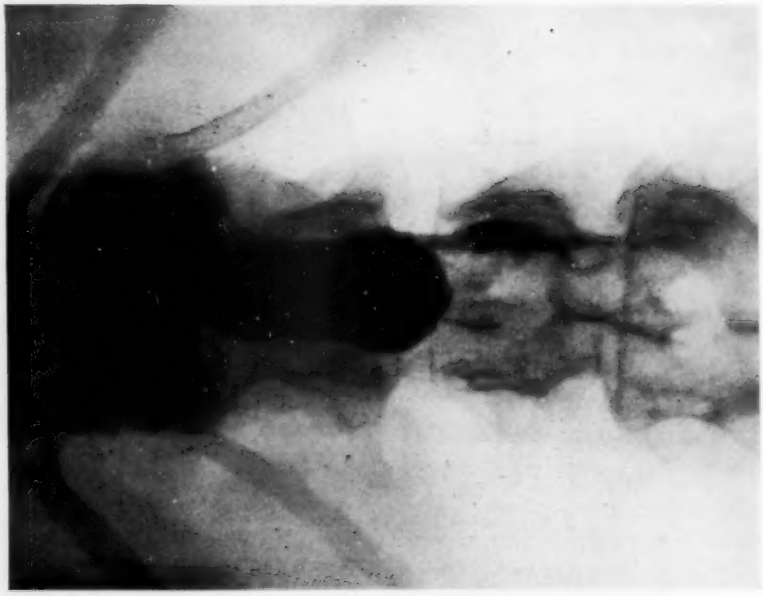

FIG. 2.—Spinal block. Anteroposterior view.

FIG. 4.—Plate taken immediately after injection of emulsion into the lateral ventricle. Anteroposterior view.

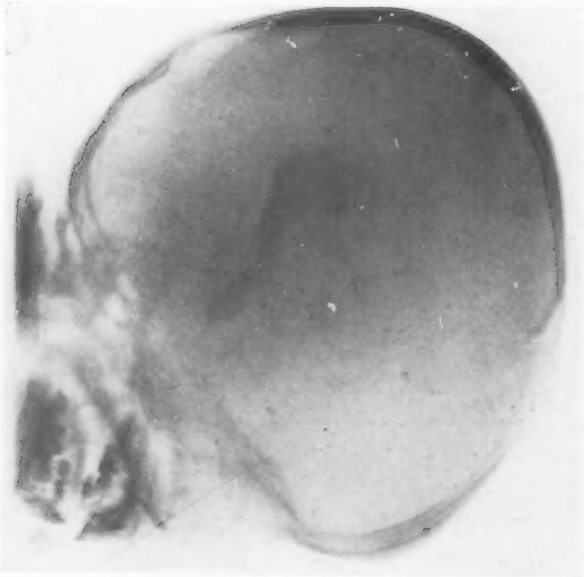

FIG. 5.—Lateral view.

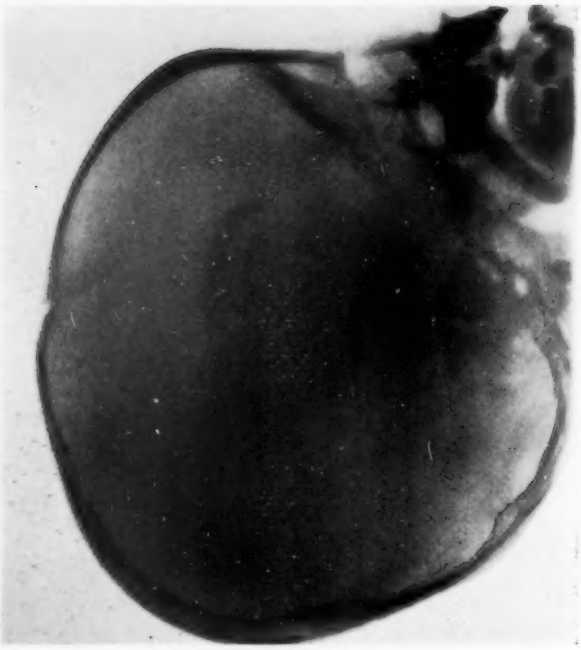

FIG. 7.—Lateral view.

FIG. 6.—Anteroposterior view three hours later. Diffusion into opposite ventricle.

the cerebral ventricles, and of the subarachnoid spaces. In order to make available the results of X-ray investigation, it is necessary to utilize methods which will permit contrast shadows.

In the intestinal tract this has been obtained by the use of the barium meal. As yet this is not entirely satisfactory. In the small intestine the fragmentation of the meal makes interpretation highly unsatisfactory. For ventriculography and encephalography air has been used. These procedures require considerable time and are not entirely devoid of danger. In the kidney pelvis sodium iodide has proved quite satisfactory.

With the introduction of the iodized poppy-seed oil for röntgenographic exploration by Sicard and Forestier,[1] in 1923, the röntgenologist had added a valuable adjunct to his armamentarium. Realizing the important, although limited, use of the iodized oils in cerebrospinal visualization, my interest was aroused in the subject. The results of our preliminary experiments have been reported by Glaser[2] and myself elsewhere.

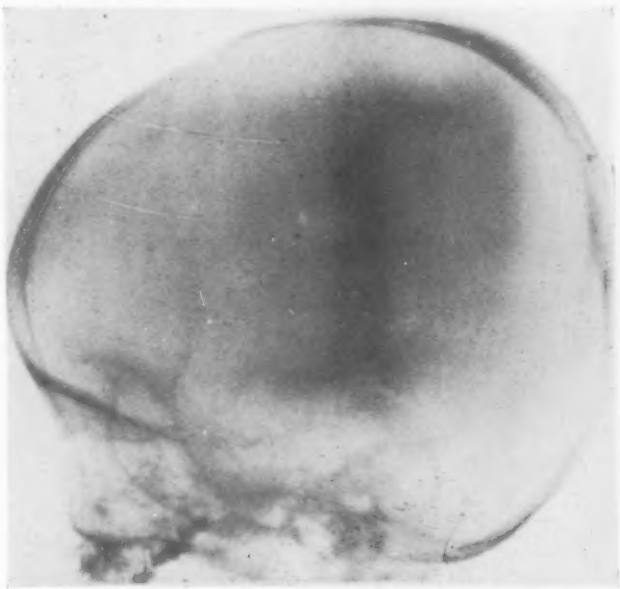

FIG. 8.—Forty-eight hours later. Disappearing of the oil.

After investigating various elements in solution and incorporated with oils, we were convinced that iodine was the most suitable element for use where shadow-casting properties were desired. The solutions of iodine, iodides, iodates, or periodates were unsuitable for general use. Some of these were well tolerated in the kidney pelvis where they could be drained after röntgenography, but they gave rise to toxic phenomena when injected into the subarachnoid space. We found that the iodized oils as a group were much better tolerated wherever used. Many oils were investigated during the work and we concluded finally that rape-seed oil, which is obtained from Brassica campestris, was the most suitable for general purposes. This oil, which comes from the family of Cruciferas, is non-irritating when injected into the subarachnoid space. It has a low specific gravity (0.913) and is of low viscosity (250 at 100° F). It is well tolerated in large amounts regardless of the site of its administration. It has been employed for cerebrospinal, pulmonary, urological, vascular, and sinus visualization.

For routine work we have used a mixture of four parts of iodized rape-

seed oil (specific gravity 1.289) with one part of ethyl olive oil. The specific gravity of this combination is 1.061. Ethyl olive oil is much less toxic as a diluent than olive oil when used for cerebrospinal visualization. To this preparation the chemists have given the name campiodol.

When, after a careful neurological examination, doubt exists as to the presence or absence of spinal block, this can be demonstrated by the injection of iodized oil. Figure 1 is an illustration of the spinal subarachnoid space of a dog after the injection of campiodol. This animal was alive and well four months after the injection. Figures 2 and 3 illustrate the use of the oil in a case of spinal block. After the injection of the oil, either by lumbar or cisternal puncture, we observe the flow by reversing the position of the patient on the fluoroscopic table. An advantage of iodized rape-seed oil is its lack of globulation and its free flowing properties. It shows no tendency to adhere to the spinal roots, which property in some of the iodized oils gives rise to the so-called false block.

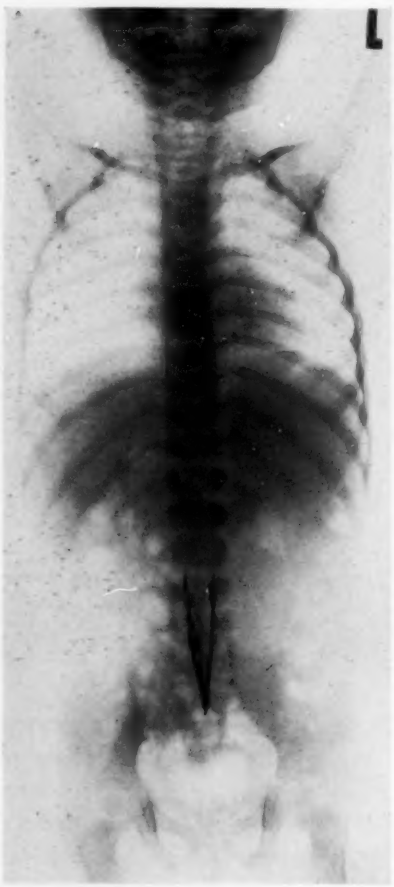

FIG. 9.—Spinal sac forty-eight hours after ventricular injection of the emulsion.

In the demonstration of the cerebral ventricular system we have met with many difficulties. We had hoped to be able to prepare a pseudo-emulsion with cerebrospinal fluid which would diffuse itself throughout the ventricles after injection. Various dilutions of the oil have been used, but we have not as yet obtained a shadow as good as that obtained by air injection. We have since tried campiodol emulsions using a highly purified acacia in the smallest possible amount. In a recent case (Figs. 4, 5, 6, and 7) we obtained an excellent ventricular shadow. The emulsion injected into one ventricle rapidly diffused into the opposite ventricle and was found twenty-four hours later in the lower portion of the spinal subarachnoid sac. (Figs. 8 and 9.) In some instances there has been a marked increase in cerebrospinal pressure after the injection, doubtless due to the osmotic effect of the acacia. This aspect of the problem is intriguing, but will require further investigation before we would advise its use as a substitute for air ventriculography.

Vascular visualization has been attempted by a number of investigators (Moniz,[3] Brooks,[4] Carnett [5]) but, for numerous reasons, has not been exten-

sively employed. The use of any material which is to any extent irritating is contraindicated. In peripheral vascular disease they may lead to further thrombosis and subsequent gangrene. Campiodol was so well tolerated by the delicate subarachnoid tissues that we have used it for demonstrating the circulation of the cranial and peripheral vessels. We have frequently injected as much as five cubic centimetres without any untoward effect. Doctor Lacey has used this method as a graphic check after vascular occlusion in his study of experimental non-union and has subjected a number of animals to two or more injections. It would be supposed that the injected oil would give rise to fat embolism, but we have never observed such phenomena in our experimental work. In this instance an animal was used which had had a subarachnoid injection by cisternal puncture six months previously. Figures 10 and 11 demonstrate the vessels of the dog's and of the cat's hind leg. This method of vascular photography has many possibilities and will no doubt find a wide field of usefulness. Figure 12 is an X-ray of the dog's head after an injection of the oil into the carotid artery.

FIG. 10.—X-ray (positive) picture of vessels of dog's hind leg.

The X-ray picture must be taken at the time of the injection of the oil since within one minute after injection nearly all traces of the oil have disappeared. We are not quite sure as to the method of disposal of the oil after injection, but we are sure that oil embolism has not occurred.

In the lung the bronchoscopist has made use of iodized oil as a contrast media for some time. The iodized oils have aided in the interpretation of certain pulmonary disorders much as has the barium meal in gastro-intestinal disease. The necessity of utilizing a substance which is non-irritating to the sensitive alveolar mucous membrane prevented the use of any substance not well tolerated. Figures 13 and 14 are X-ray pictures of the chest after the injection of iodized rape-seed oil into the bronchi of a patient suffering from bronchiectasis. It shows clearly the dilated and "clubbed" bronchi. At the

present time this method is the best at our disposal for determining the extent of the lesion.

Occasionally, the surgeon wishes to ascertain whether or not there exists a stricture in the common duct after operations for the removal of a stone. At the University Hospital campiodol has been introduced both into the gall-bladder and into the common duct, when an external biliary fistula exists, in

FIG. 11.—X-ray picture of hind leg of cat after injection of campiodol into the femoral artery.

order to determine the patency of the cystic and common ducts. Figure 15 shows an injection of the common duct of a cat with campiodol. The oil has not only entered the duodenum, but it has entered the intrahepatic bile ducts and clearly outlined them.

The oil may be used to advantage to determine the route and origin of old sinus tracts. Figure 16 was taken from a case of Dr. E. L. Eliason's. The oil can be seen clearly entering a large cyst, probably of pancreatic origin.

The gynæcologist has used iodized oils in order to determine the patency of the Fallopian tubes and the urologist for outlines of the kidney pelvis.

We have applied the oil in the experimental laboratory in an attempt to visualize non-opaque pelvic calculi. Doctor Muschat has been able to demonstrate these by injecting the iodized oil and then withdrawing it. Sufficient of the oil remains then to cast a shadow outlining the calculi. In urologic practice the application of oil in this way should be of material advantage.

In sinus disease the iodized oils have a wide field of usefulness in the hands of the otolaryngologist. The demonstration of new growths, polypi, and thickened mucous membrane can be more easily and accurately made than by any other technic.

FIG. 12.—Injection of campiodol into the carotid artery of the living dog.

The question naturally arises, are these oils after iodinization inert? We have given dogs from six to seven cubic centimetres per os of undiluted campiodol per kilo of body weight without any untoward symptoms. The studies we have made on dogs, and those made by Doctor Raiziss on smaller laboratory animals, have led us to conclude that straight iodized rape-seed oil, diluted or not with ethyl olive oil, is less toxic than a solution of sodium iodide containing a similar amount of iodine. The straight oil contains 40 per cent. of iodine. The cell count of the spinal fluid after subarachnoid injection of the oil has varied in the dog from 250 to 800 per cubic millimetre. The highest count obtained after the injection of the oil into the human subarachnoid space has been 310 cells per cubic millimetre.

We have had no untoward effects after the injection of the oil into the peripheral vascular system, and the procedure has been carried out many times. In fact the only reactions observed have been after injections into the ventricles. The iodine is very slowly liberated and then in very small amounts. In a patient into whose ventricles campiodol had been injected four months

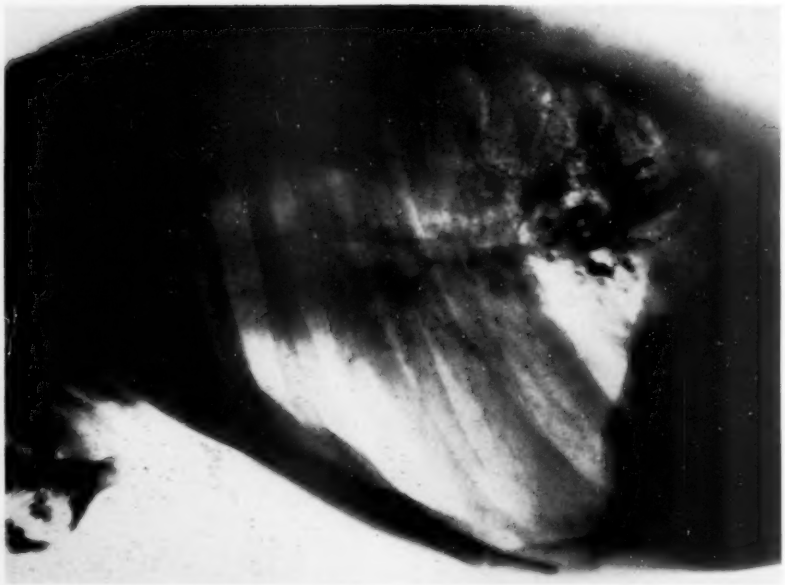

FIG. 14.—Same. Lateral view.

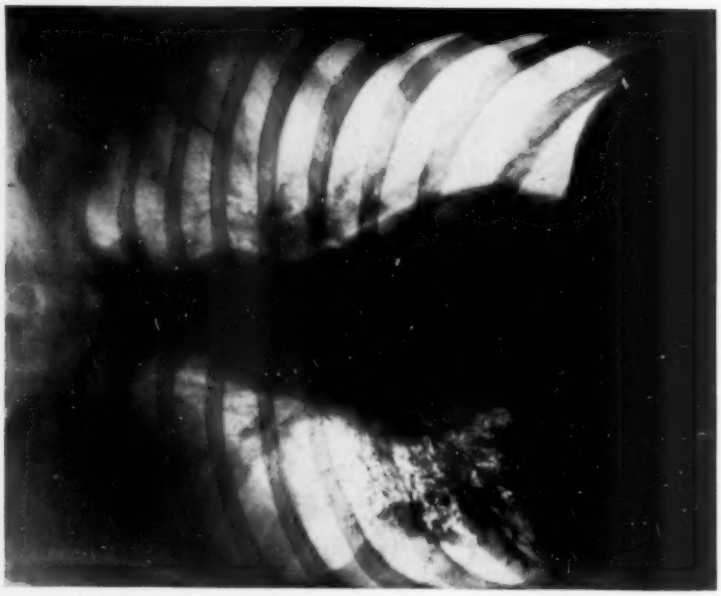

FIG. 13.—Case of bronchiectasis. Campiodol injection.

previously, we were unable to find any free iodine in the cerebrospinal fluid, although X-ray pictures still showed opacity produced by the iodized oil.

Here, however, the problem is complicated by the introduction of another factor, since in the ventricular injections we have felt obliged to use an emulsion. Up to the present time we have not found an ideal emulsion and this phase of the problem is still under investigation.

It is our belief at this time that in iodized rape-seed oil, campiodol, we have as inert a material as it is possible to obtain for shadow-casting purposes when injected into the internal organs. Its high iodine content, the stability of the iodine linkage to the oil, and the fact that rape-seed oil contains very little of the acids which are irritative in character, makes it an ideal product.

We are deeply indebted to Dr. George Raiziss, of the Dermatological Research Laboratories, for his aid in this work.

FIG. 15.—Injection of the extra- and intrahepatic biliary system with the iodized rape-seed oil. The oil can be seen entering the duodenum.

## CONCLUSIONS

1. The iodized oils have a definite use in the röntgenographic exploration of some of the internal organs.

2. Iodized rape-seed oil, campiodol, has proven a highly satisfactory preparation for this type of exploration.

3. It is well tolerated by all types of tissue.

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DISCUSSION: DR. DAMON B. PFEIFFER said that a recent experience had made him realize the need of a less irritating material than lipiodol for use in the diagnosis of chest diseases. Briefly, it concerned a young man with bron-

chiectasis of the lower lobe of the left lung, very like one of the pictures shown by Doctor Frazier. One year ago he had a bronchiectasis abscess which ruptured into the pleura, resulting in a massive empyema for which a rib resection was done. Since that time he has been trying to secure closure of a number of bronchial fistulas. Phrenicectomy and local collapse of the chest wall have been tried without avail. The speaker finally considered radical

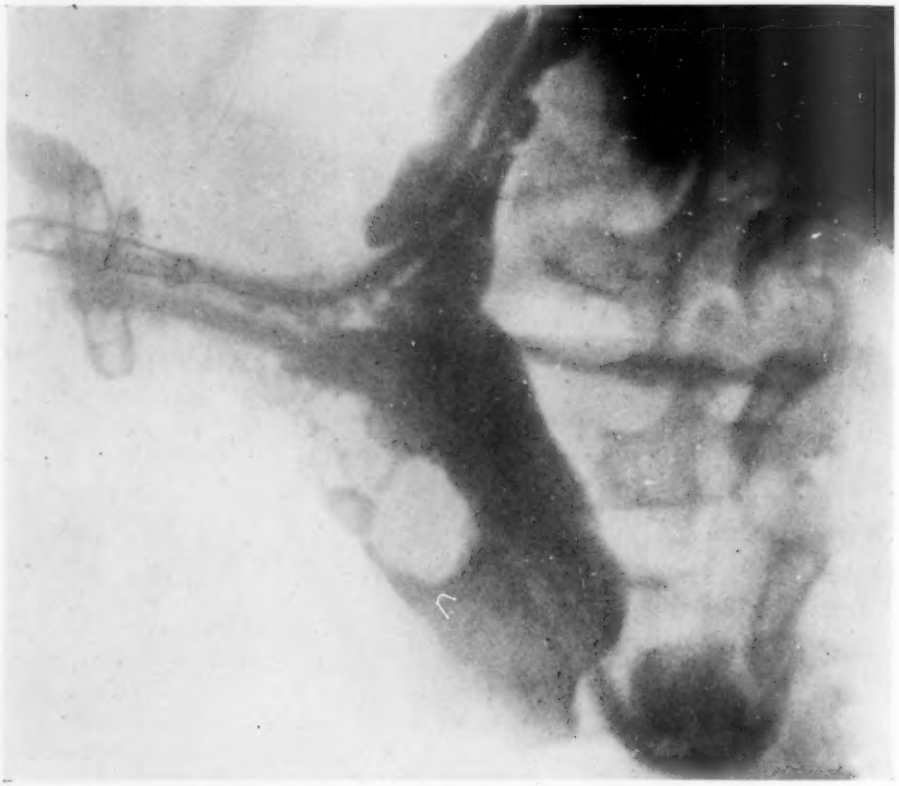

FIG. 16.—Iodized rape-seed oil after injection into an abdominal sinus.

extrapleural thoracoplasty and asked the bronchoscopist to introduce lipiodol for information as to the condition of the lower lobe. He did it skilfully, the picture was satisfactory and the information also, but the boy, who had up to that time been producing only small amounts of exudate, began to discharge large quantities of pus from the fistulas, showing that the lipiodol was extremely irritating in its action. Archibald and others have called attention to the irritation of lipiodol and this contribution of Doctor Frazier's may be of first importance in providing a substance which may be used to obtain valuable information not only in the lung but in various other cavities and sinuses without the liability to cause an exacerbation of the underlying conditions. The speaker wished to ask Doctor Frazier whether campiodol is generally available at this time.

# NON-UNION OF FRACTURES *

## AN EXPERIMENTAL STUDY

By James T. Lacey, M.D.

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From the Laboratory of Research Surgery and the Department of Surgery of the University of Pennsylvania

Aided by a grant from the Harriet M. Frazier Fund for Research in Surgery

The causes of non-union of fractures have been widely discussed. Generally, they are divided into two groups—systemic and local. Nearly every writer on this subject mentions syphilis, rachitis, bone dystrophies, bone tumors, osteomyelitis, and countless other general affections. Peterson [1] and Taylor [2] have many followers of the theory of calcium and phosphorous deficiency as the cause of the delay in union. The glands of internal secretion are believed by Marsiglia [3] and Kolondy [4] and others to have a controlling action on bone repair.

Several questions naturally arise in discussing these systemic causes. One must recall the multitude of luetics and rachitics whose fractures heal without delay while, as to the glandular and inorganic salt theories, one wonders why, if these theories are correct, non-union so frequently picks particular sites in the body. Henderson [5] states that constitutional disease is practically never responsible for non-union and, in his series of 259 cases of non-union, the lower end of the tibia and the middle of the humerus stand out as the most frequent sites of non-union. When one excludes non-union of the femoral neck in the aged, these two sites comprise the large majority of the cases observed by the surgeon. Non-union of the clavicle, for example, is rare; yet this bone is probably the most frequent site of fracture. Also against the systemic theory, those cases of multiple fracture stand out in which only one fails to unite. Campbell,[6] Ravdin and Jonas,[7] Ravdin and Morrison,[8] and Henderson [9] could not agree with Peterson [1] that the calcium and phosphorous index could be used as a prognostic index of union or non-union.

It would seem, then, that, if a single cause for non-union were to be found, which I do not believe to be possible, the systemic causes must be discarded in favor of the local causes. Of these, the interposition of soft parts and foreign bodies will not be considered because they are easily remedied and do not belong in the real problem of non-union. In this connection Forrester-Brown [10] states that the periosteum itself, if interposed, will inhibit union. Neither will the malposition of the fragments be considered, for, although they often unite despite the malposition, it is the case of non-union in which alignment and apposition has been good that presents the real problem.

The question of immobilization of the fragments may or may not be a factor. Writers differ on this point, but the movement of the fragments pro-

* Read before The Philadelphia Academy of Surgery, March 4, 1929.

tected only by a brace for the non-operative treatment of non-union is recommended almost universally for established delayed union or non-union. Henderson [5] mentions inadequate fixation as a cause of non-union in sixty-three per cent. of his 259 cases. Warner,[5] in discussing Henderson's paper, states that rapid union may take place with poor fixation. Thus, the question of fixation does not seem to be the all-important factor.


FIG. 1.—A1, sixteen days after fracture. There is a moderate external callus formation.

As regards the type of fracture, excluding the fracture similar to the war fracture where loss of bone substance is common, most of the cases of non-union occur in simple fractures. Stern,[5] in discussing Henderson's paper, states that the ordinary compound fracture does not result in non-union. Similarly, a pathological fracture due to osteomyelitis may be seen to unite after drainage has been instituted, while pathological fractures associated with metastatic malignancy often unite.

Essential to the repair of any injury is the blood supply to that part. In the repair of simple fractures, Blaisdell and Cowan [11] summarize four points: (1) The periosteum is more or less lacerated, stretched, and loosened from the bone; (2) the blood vessels in the vicinity of the fracture line are ruptured and closed by clots; (3) the processes of repair are in part modified by the state of nutrition. Robinson,[12] describing the vascular changes at the fracture site, states that the inter- and intra-osseal vessels are ruptured by the fracture and promptly thrombose. The clot formed between the fragments is replaced by granulation tissue into which blood vessels grow transverse to the long axis

of the bone. These new vessels are outbuddings from the vessels about the fracture site. Kolondy [13] states that the endosteum is not able to participate in the repair until an anastomosis is formed between inter-osseal vessels of the central portion of the nutrient artery and the metaphyseal vessels. Drinker, Drinker, and Lund,[14] in their perfusion experiments on the blood vessels of the tibia, found that the blood supply was from three sources: (1) Minute periosteal arteries springing from the fascial and muscular twigs that pass near the bone; (2) many moderate-sized vessels entering near the ends of the bone and frequently terminating within the marrow cavity; and (3) the nutrient artery which in the adult tibia may be considered in series with the arteries of Group II. With the nutrient artery ligated, injection of the vessels of the tibia was almost as complete as where the nutrient artery was not tied. Where the nutrient artery alone was injected, the lower end of the bone was not as completely injected. One of their animals happened to have an old fracture of the tibia at the junction of the middle and lower third of the tibia. No twigs of the nutrient artery crossed the fracture line. The bone below the fracture received its blood supply from the periosteal vessels and from the vessels entering the bone from the lower end. Johnson[15] established very clearly the anatomy of the vascular supply of the tibia. Like Drinker, he divides the supply into three groups, the nutrient artery, the metaphyseal vessels, and the periosteal vessels. He found that the nutrient artery gave the greatest blood supply and was capable of carrying on the supply for the whole tibia. The metaphyseal vessels were almost equal in potency. They supply the entire bone with only slight deficiency in the centre of the shaft. The periosteal vessels, however, he found did not extend below the cortex. Johnson agreed with Peterson's calcium and phosphorous index theory, but

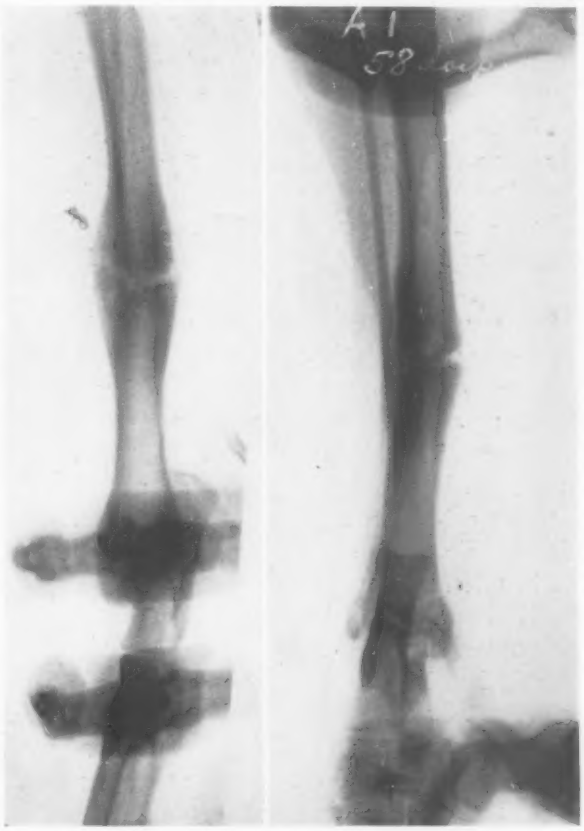

FIG. 2.—A1, fifty-eight days after fracture. The bones have united in good position with extensive external callus.

thought more important the vascular network by which these building materials reached the fracture. Eliason,[16] in an experimental study of non-union of the lower third of the tibia, brought out some important features about the anatomy of the lower third of the tibia. The vessels, nerves, and tendons are all compactly enveloped in the deep fascia. Swelling in this area causes

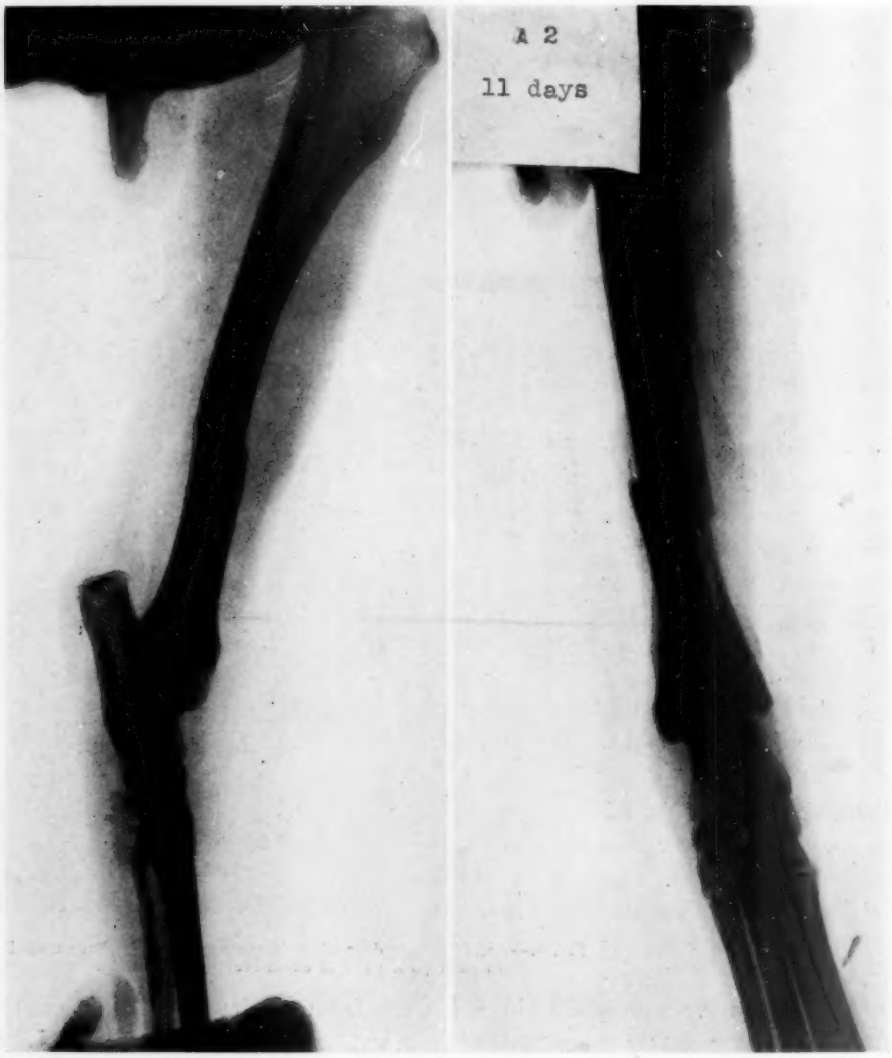


FIG. 3.—A2, eleven days after fracture. No evidence of callus formation.

a lessening of the dorsalis pedis pulse. The anterior tibial artery lies next to the bone with no intervening muscle, and it is this artery which supplies the greater portion of the blood to the lower end of the bone. In cases of non-union, the affected side is often cooler, the dorsalis pedis pulse weaker, and the blood pressure is invariably lower. The lower fragment shows osteoporosis

and less callus than the upper fragment by X-ray. He fractured the tibias of twelve dogs, four of which were controls, and in eight he ligated the anterior tibial above the fracture site. All united within four weeks, but in five of the ligated dogs, union was less firm and there was less callus as compared with the controls. Campbell [17] mentions severing of the nutrient artery

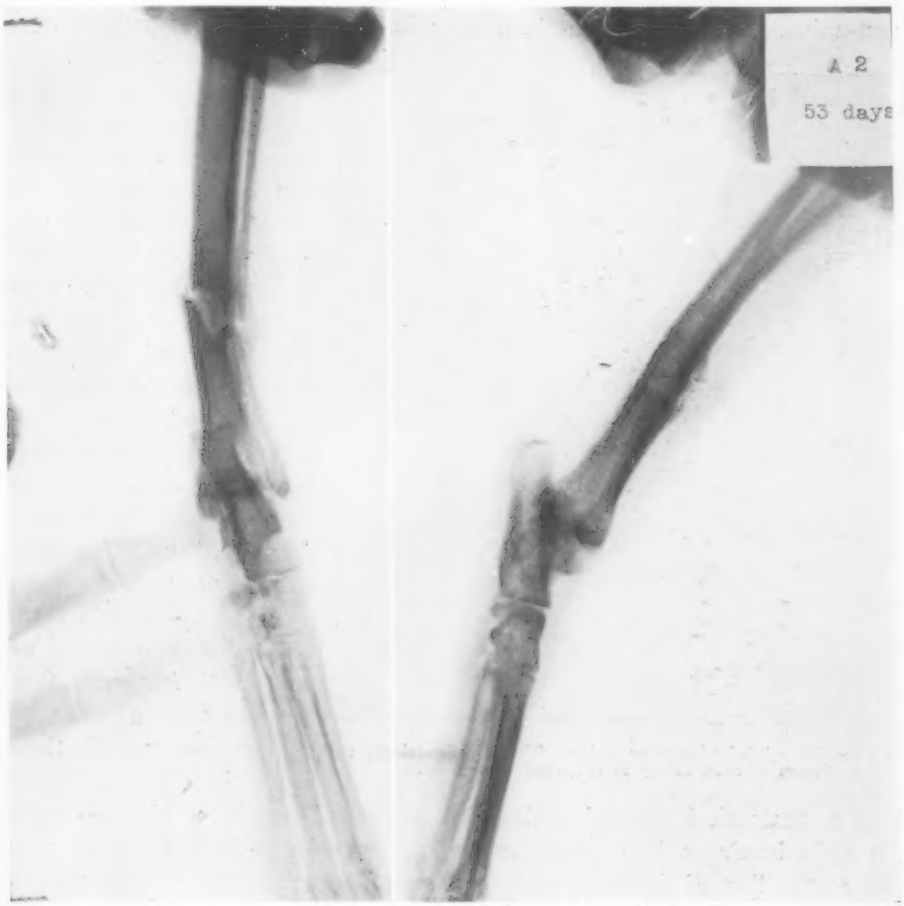


FIG. 4.—A2, fifty-three days after fracture. Slight increase in callus formation, increased density of the bones.

as a cause of non-union. Kolondy [4] injected specimens of fractures and demonstrated beautifully the increased vascular supply at and near the fracture site as compared with a non-fractured bone. Todd [18] states that bone regeneration is easily affected by pressure, even of the soft tissues. Geist [19] showed that a new Haversian system develops in bone after injury about the seventeenth or nineteenth day, at which time the internal and external callus becomes absorbed. Estes [20] gives as one of his causes for non-union insufficient blood supply at the seat of the fracture. Bancroft [21] like Johnson [15] calls attention to the fact that the calcium and phosphorous used in bone repair come from the circulating blood as well as from the ends of the fragments. Nutter [22] and Block [23] mention interference of the blood supply associated with too

tight dressings as a cause for non-union. Kolondy [13] believes that destruction of the periosteal blood supply leads to non-union. His experiments, however, were only continued for forty-two days after fracture. Ely,[24] in his work on the periosteum, agreed in part with Kolondy, but he also considered a fracture ununited after thirty-three days. With this we cannot agree. Henderson [25] included injury to blood vessels, muscles, and fascia as factors in non-union. He believed that hematoma in connection with fractures were a hindrance to union.

FIG. 5.—A2, oil injection after union. The injection shows the anterior tibial artery to be patent throughout.

In summing up this review of the literature, it seems logical to choose the blood supply of the bones as starting point to study the cause of non-union of fractures. Furthermore, it appears that this cause of non-union is to be found at the fracture site and there is nothing more vital to the healing of a fracture than its blood supply. With every fracture, there is a greater or lesser degree of trauma to the soft parts. In Henderson's [5] 259 cases of ununited fractures, 118 were associated with severe trauma. If, then, such fractures occurred in the anatomical sites described by Eliason [16] or were dressed with too tight bandages in addition to the rupture of the intrinsic blood vessels at the line of fracture, there would exist a condition of malnourishment of the distal fragment likely to result in non-union. The foregoing statement gives a condition which is ample cause for non-union. In addition, then, poorly reduced, insufficiently immobilized, and mismanaged fractures are still more likely to be delayed in uniting, or fail to unite at all.

*Method.*—With the study of Eliason in mind, the following experiment was planned. Adult dogs were used throughout. One of the most frequent, if not the most frequent, sites for non-union of fractures—namely, the junction of the middle and lower thirds of the tibia—was chosen as the fracture to be studied. Fracture by operation was selected over closed fracture for sake of accuracy. In the control animals, nothing further was done. In another series, the anterior tibial artery was doubly ligated and cut between the ligatures in addition to fracture of the tibia.

The general technic of the operation was similiar in each case. The operations were carried out with strict asepsis. The entire lower extremity was shaved and prepared with iodine. The anæsthesia in the first few animals was ether. This, however, was discarded in favor of the intraperitoneal injection of sodium amytal. Ample incision was made over the crest of the tibia, and in the controls and ligated animals the periosteum of the tibia was

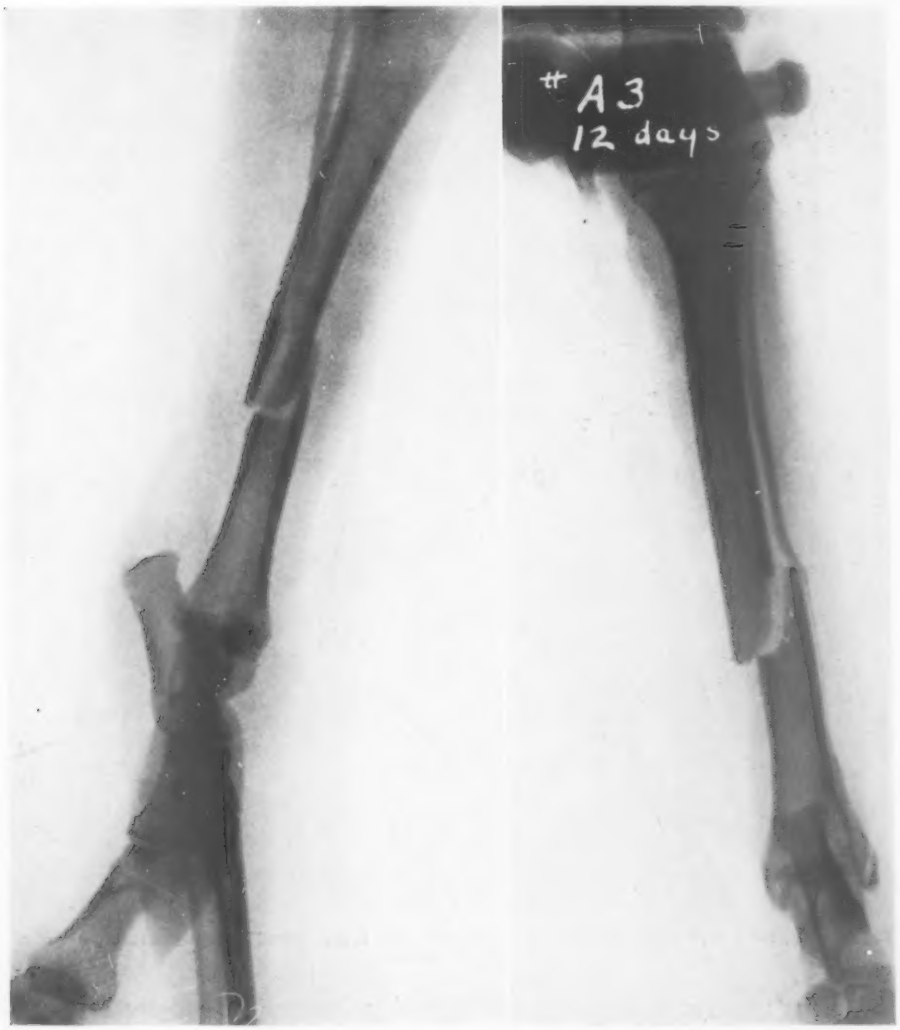


FIG. 6.—$A_3$, twelve days after fracture. No evidence of callus formation.

split longitudinally at the junction of the middle and lower thirds of the tibia. With the periosteal elevator, the periosteum was freed from around the bone sufficiently to allow the bone-cutting forceps to be inserted between it and the bone. The bone was then cut through with the forceps, or nearly cut through and the break completed by manipulation. In the reduction of the

fracture, an effort was made to secure only three-quarters end-to-end apposition. It was found by Ravdin and Morrison [8] that this procedure gave a more satisfactory X-ray picture. The split in the periosteum was then sutured and the fascia and skin closed. Lateral plaster moulded splints were applied from the middle of the femur to, and including, the toes. The splints were allowed to harden before the anæsthesia was discontinued. In the cases in

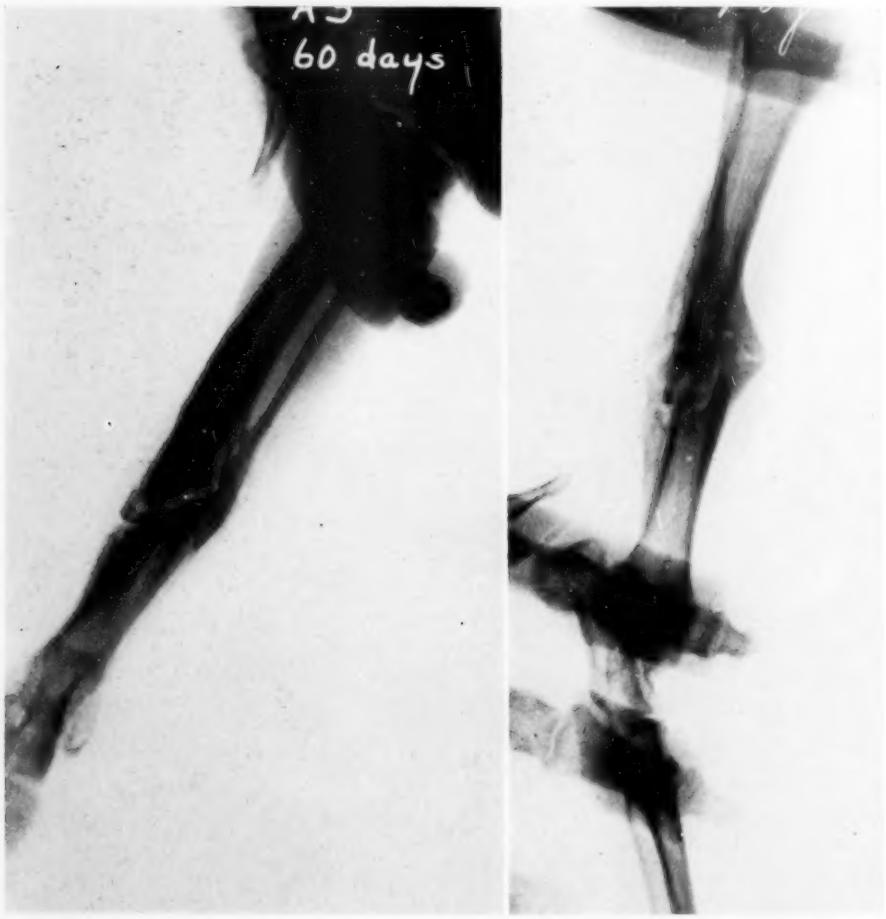


FIG. 7.—A3, sixty days after fracture. The fragments are firmly united with slight absorption of the external callus.

which the anterior tibial artery was ligated, a longer incision was made and the artery isolated at the level of the upper third of the tibia. Two ligatures were passed about the artery and tied and the vessel cut between the ligatures. The splints were removed within a week to ten days after operation in all cases and the wound examined. Immobilization was continued until sufficient callus had formed to hold the fragments together in position. In a very few instances, there was infection in the wound or ulcers developed at distant points due to pressure of the splints. These promptly healed under antiseptic

treatment and in only one instance was the bone exposed. X-ray in this case failed to reveal any evidence of osteomyelitis. The animals were X-rayed two weeks after operation and thereafter every week or two depending on the previous X-ray report.

About the time these experiments were being carried out, campiodol, a new iodized oil, was being prepared under the direction of the Laboratory of

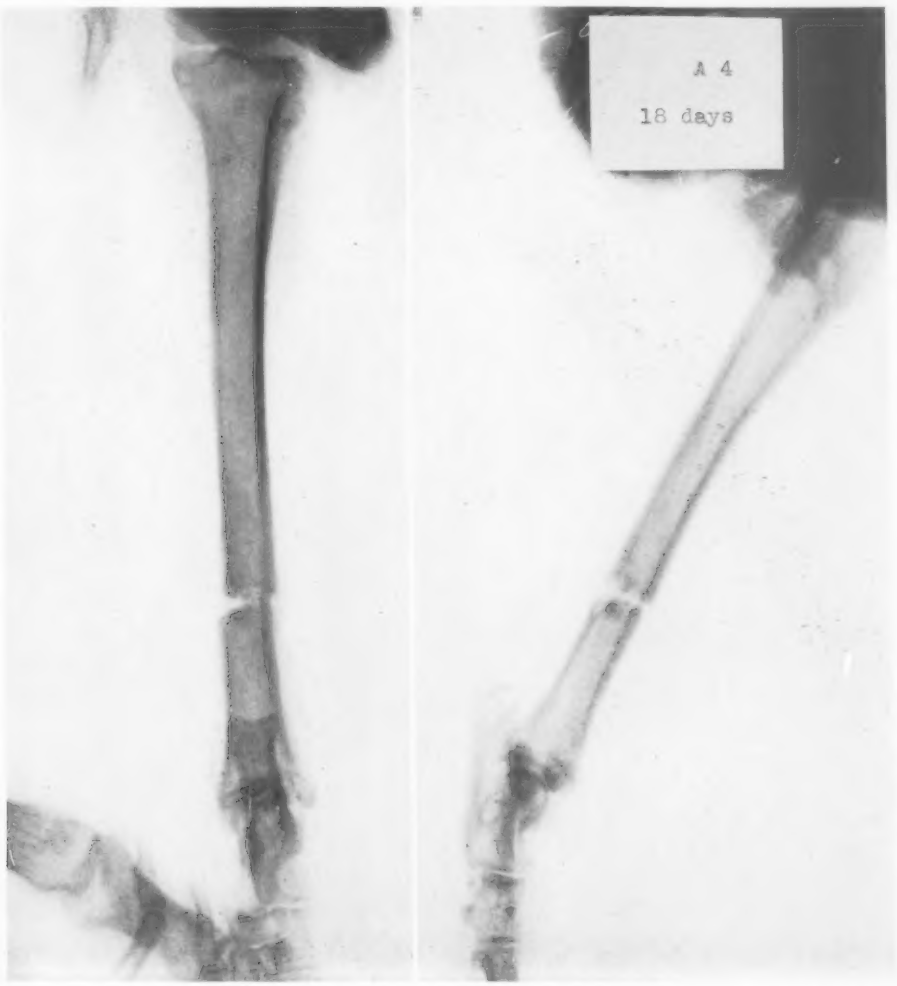


FIG. 8.—A4, eighteen days after fracture. The amount of callus is regarded as abnormally slight.

Research Surgery by Frazier and Glaser.[26] One of the control animals had gone for seventy days without osseous union and it was thought that the anterior tibial artery might have been injured at the time of fracture. To determine patency of this artery, the femoral artery was injected with two cubic centimetres of the opaque oil and an X-ray photograph taken immediately following the injection. (Fig. 5.) A most satisfactory visualization of the vascular tree of the extremity was obtained. Not only was the anterior

tibial artery found to be intact, but also a very extensive collateral circulation was seen about the fracture site. The success of this injection prompted the use of campiodol as a means of controlling future experiments. Accordingly, another animal was operated on, the anterior tibial artery ligated, and the tibia fractured. Injection was done at the completion of the operation while

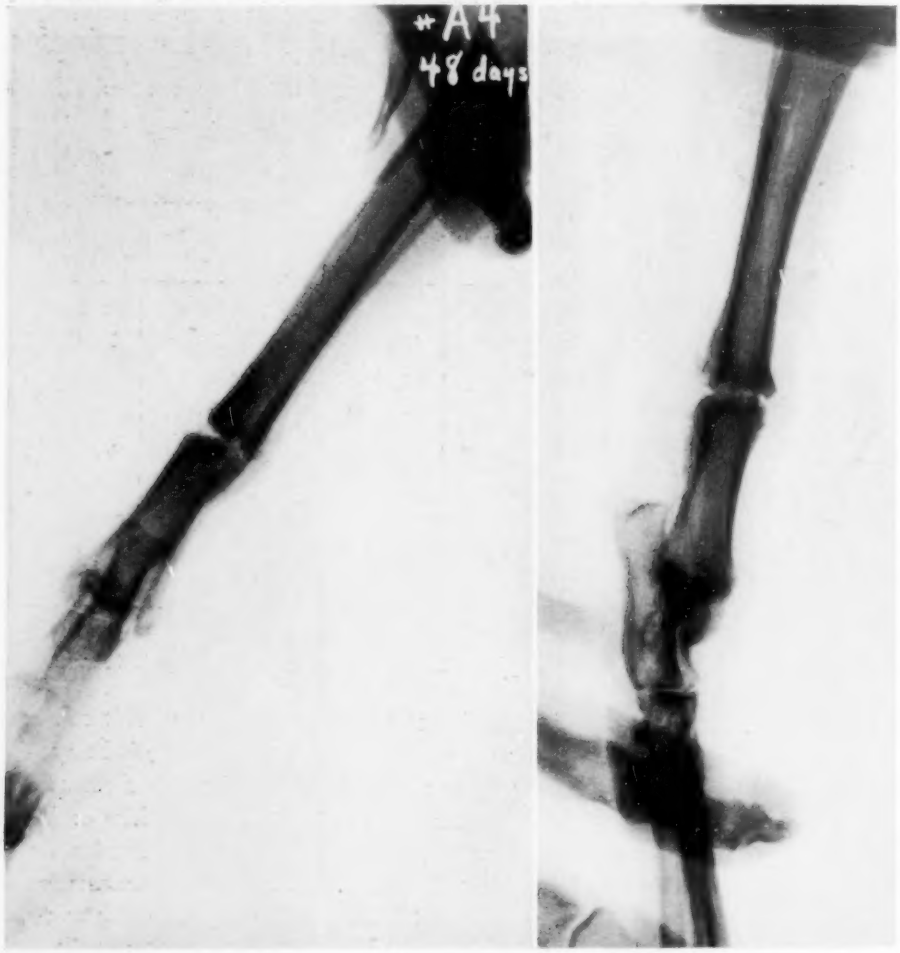


FIG. 9.—A4, forty-eight days after fracture. Callus formation is slightly increased. Presumably there is now definite union.

the animal was still under amytal anæsthesia. The information gained from the X-ray of this injection (Fig. 17) showed that the necessary condition described above for the development of non-union had not been accomplished. The lower end of the ligated artery was receiving blood from the branches of the dorsalis pedis artery which anastomosed with branches of the posterior tibial artery. In order to wholly occlude the anterior artery, it was necessary to ligate the dorsalis pedis artery in the foot, thus preventing the collateral circulation through the foot from the posterior tibial artery from supplying the lower fragment.

Up to this point, as shown in Table I, a longer period of time was required for the bony union in the control animals than in the ligated animals. In the next animal (Fig. 19) both the anterior tibial and the dorsalis pedis arteries were ligated and the tibia fractured. The injection shows both ligations. This animal developed the typical picture of non-union as seen clinically by the X-ray. Unfortunately, the animal died under amytal anæsthesia eighty-seven days after fracture and ligation of the anterior tibial and the dorsalis pedis arteries. No evidence of union had taken place and we would interpret this as evidence that union was not going to take place.


FIG. 10.—A6, eighteen days after fracture. The ends of the bones are rather dense. There is no visible callus formation.

From this point all experiments were carried on in a similar manner, *i.e.*, ligation of the dorsalis pedis as well as the anterior tibial artery together with the usual fracture. The results are tabulated in Table I. These results do not appear to be conclusive and considerable explanation is necessary for their interpretation. It will be noted that two of the control animals, A2 and A12[2] required an exceptionally long period of time for osseus union. In the experiments of Ravdin and Morrison,[8] none of their controls took such a long time to unite. They were using, however, the ulna and radius. The explanation of this may lie in the fact that the lower third of the tibia is normally a very common site for non-union. It is likely, therefore, that in this series such cases were encountered.

To explain why the animals in which the anterior tibial artery was ligated took less time for union reverts to a physiological principle. The effort in this

problem was to produce a deficient blood supply to the lower fragment. It was, then, an error in procedure to try to accomplish this by ligating the anterior tibial artery. The blood supply *via* the nutrient artery was cut off by the fracture itself and, as Drinker [14] and Johnson [15] discovered, the metaphyseal vessels alone are sufficient to carry on the nutrition of the lower end of the tibia. If, then, in addition to the injury to the vessels of the tibia itself, the anterior tibial is ligated, the blood normally coursing that artery is shunted to the posterior tibial through the anastomosis of the foot to the dorsalis pedis and, therefore, increasing rather than inhibiting the blood supply of the lower fragment. Accordingly, early union is to be expected in this group of experiments.

TABLE I

| Group I Controls | | Group II Ligation of anterior tibial | | Group III Ligation of anterior tibial and dorsalis pedis | |
|---|---|---|---|---|---|
| Dog No. | Days for union | Dog No. | Days for union | Dog No. | Days for union |
| A2 | 70 | A1 | 58 | A4 [2] | 87 [1] |
| A9 | 59 | A3 | 56 | A9 [2] | 174 [1, 2] |
| A10 | 21 | A3 [2] | 56 | A10 [2] | 66 |
| A12 [2] | 107 | A4 | 48 | A11 [2] | 111 |
| | | A7 | 25 | B1 [2] | 88 |
| | | A11 | 30 | | |
| | | A12 | 30 | | |
| | | | | Average | 105 + |
| Average | 64 | Average | 43 | Average Less A9 [2] | 88 + |

[1] Animal died before union occurred.
[2] Animal living with non-union at completion of problem.

The third group shows more satisfying results. It is obvious from the X-ray of A4 [2] (Fig. 21) that this case is the best example of non-union in the series and would undoubtedly have progressed for a much longer period of time without union had not the animal died. The tibia of this dog was removed and cut sagitally. A white line was observed at the fracture site and there was mobility between the fragments. (See photograph, Fig. 24.) Microscopic sections (Fig. 25) revealed that the white line between the fragments was fibrous tissue showing no evidence of invasion of osseus tissue.

A9 [2] is included with reservations. For the first few weeks the animal did very well and, when fibrous union seemed firm enough, the cast was removed. There gradually developed increasing deformity of the fragments, overlapping, and angulation, which may be a factor in the failure of union. The animal is still living and has non-union. Although other works have shown union to occur in equally severe deformities, this animal was not included in the final results. Without including this animal, the average number of days required for union in Group III was twenty-four days plus longer than Group I and forty-five days plus longer than Group II.

The terminal oil injection at the completion of the later experiments offers some of the most striking features of the problem. The collateral circulation and anastomoses about the fracture site are astonishing. They show how difficult it is to reduce the blood supply at the fracture site. In dog A10 [2] (Fig. 28), for example, the segment of artery between the two ligatures is seen filled with opaque media. This could only occur with early anastomoses about the ligatures allowing blood to enter the isolated segment before that segment had become obliterated. The original oil injection of this animal, as well as the final, establishes the certainty of the ligations. These abundant anastomoses go a long way toward proving that the blood supply is an important factor in the healing of fractures. A comparison of the final injection of A4 [2] (Fig. 22) with the final injection of the controls, A2 (Fig. 5) and A12 [2] (Fig. 36) and even A10 [2] (Fig. 28) A11 [2] (Fig. 32) and B1 [2] (Fig. 40)—all of which showed bony union of the fragments—shows the anastomoses of A4 [2] to be much less abundant. This comparison, it seems, helps to establish the theory that interference with the blood supply to a fracture is an important factor in the cause of non-union.

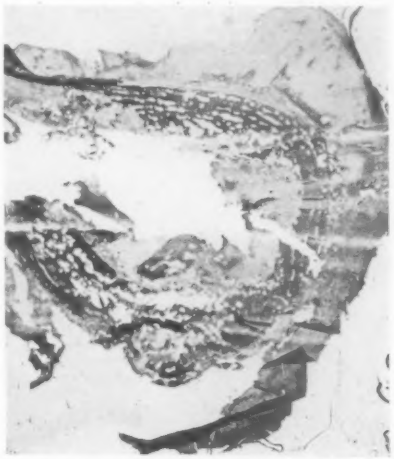

FIG. 11.—A6, eighteen days after fracture. Microphotograph of the upper fragment close to the fracture site shows considerable amount of external callus.

FIG. 12.—A6, eighteen days after fracture. Microphotograph of the lower fragment shows small amount of external callus compared with Figure 11. These sections are equidistant from the line of fracture.

## SUMMARY

An attempt has been made in Group III to produce experimentally a condition similar to a clinical case of non-union. The theoretical clinical case has been described earlier in this paper—fracture at the junction of the middle and lower thirds of the tibia (a very frequent site for non-union) with associated trauma to the soft parts resulting in swelling and compression of the vascular supply to the fragments. The results obtained bear out the theory that occlusion or partial occlusion of the blood supply to the fracture site is an important factor in the production of non-union. Group II, first planned to produce a condition suitable for the production of non-union, shows contrary results, but, in analysis, substantiates the vascular theory.

The use of campiodol for visualization of the vascular tree not only offered an excellent method of control, but substantiated the results of the problem.

## CONCLUSIONS

1. The clinical picture of non-union can be produced in the experimental animal.

2. Interference with the blood supply to the fracture site appears to be an important factor in the development of non-union.

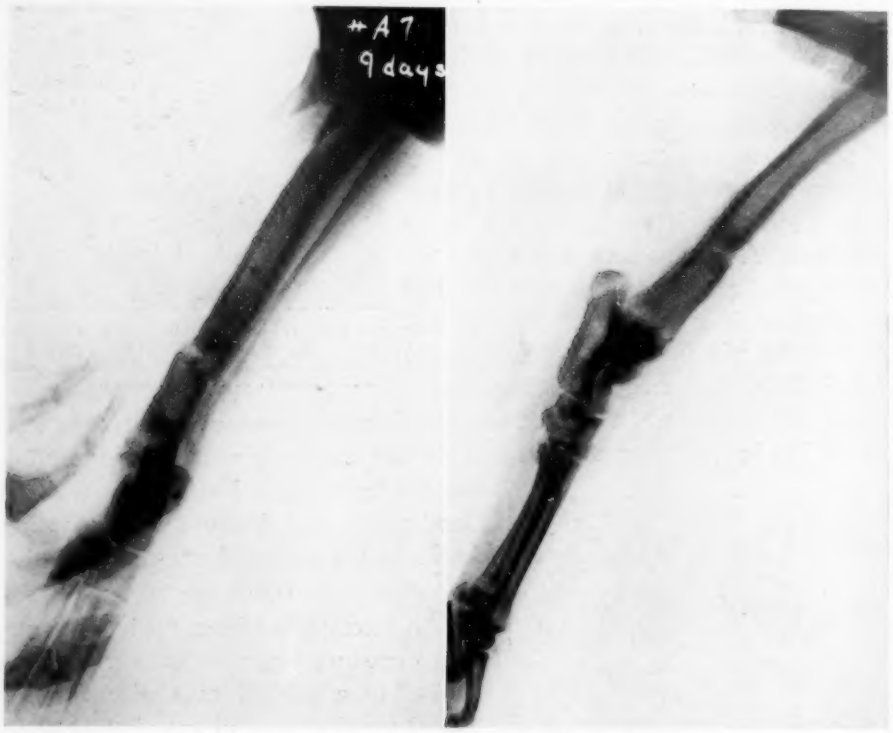


FIG. 13.—A7, nine days after fracture. Moderate callus formation.

3. Interarterial injection of campiodol affords an excellent means of controlling experiments dealing with the vascular system.

The author is deeply indebted to Dr. E. L. Eliason for inspiration, to Dr. I. S. Ravdin for careful guidance, and to Dr. E. P. Pendergrass for interpretation of the X-ray films.

## PROTOCOLS

A1.—Dog, tan and white, long-haired male, medium size. *Operation.*—December 15, 1927, ligation of the anterior tibial artery and fracture of the tibia. December 31, 1927.—Sixteen days after fracture. X-ray: There is moderate external callus formation. January 21, 1928.—Thirty-seven days after fracture. X-ray: Callus is absorbed to some extent. February 11, 1928.—Fifty-eight days after fracture. X-ray: The bones have united in good position with excessive external callus. Experiment concluded.

A2.—Dog, brown, short-haired female, medium size. *Operation.*—December 20, 1927, fracture of the tibia. December 31, 1927.—Eleven days after fracture. X-ray: No evidence of callus formation. January 21, 1928.—Thirty-two days after fracture. X-ray: External callus formation is slight. February 11, 1928.—Fifty-three days after fracture. X-ray: Slight increase in callus formation. Increased density of the bones. February 20, 1928.—Sixty-two days after fracture. X-ray: Practically no change since last examina-

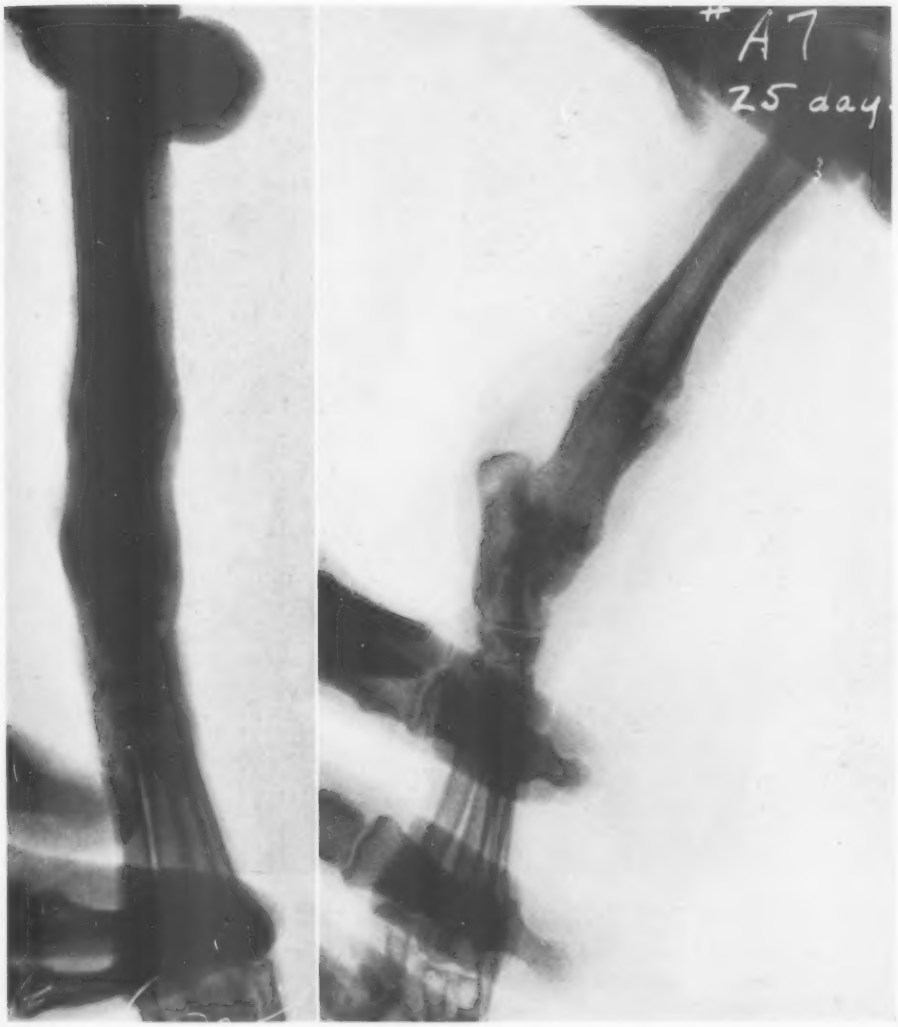


FIG. 14.—A7, twenty-five days after fracture. The bones are firmly united. The callus formation is more marked than in Figure 13.

tion. Slight absorption at the line of fracture. February 28, 1928.—Seventy days after fracture. X-ray: There now appears to be osseous union. March 5, 1928.—Oil injection. X-ray: Excellent injection of the vessels, showing the anterior tibial artery to be patent throughout. Experiment concluded.

A3.—Dog, medium size, tan and white, long-haired female. *Operation.*—December 22, 1927, ligation of anterior tibial artery and fracture of tibia. January 3, 1928.—Twelve days after fracture. X-ray: No evidence of callus formation. January 21, 1928.—Thirty

days after fracture. X-ray: Very slight external callus formation. February 16, 1928.—Fifty-six days after fracture. X-ray: Callus excessive, fragments firmly united. There is increased density of ends of bone, probably due to endosteal bone formation. February 20, 1928.—Sixty days after fracture. X-ray: Fragments are firmly united with slight absorption of external callus. Experiment concluded.

A4.—Dog, medium size, tan, short-haired female. *Operation.*—January 3, 1928, liga-

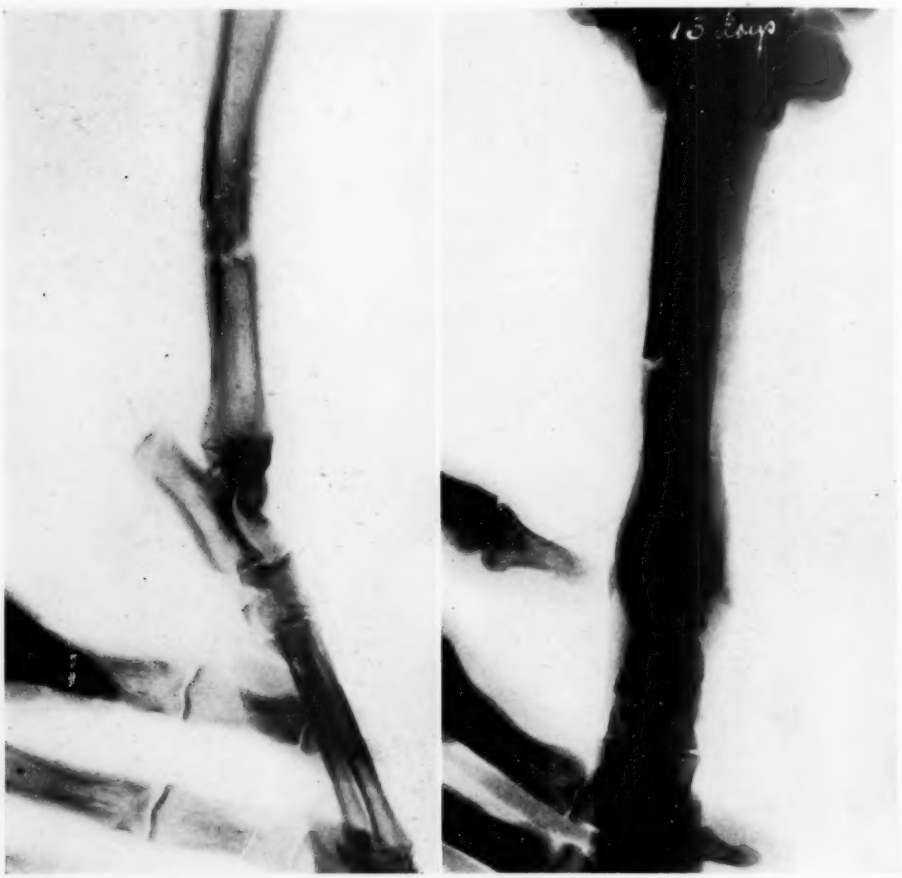

FIG. 15.—A10, thirteen days after fracture. Moderate callus formation.

tion of anterior tibial artery and fracture of tibia. January 21, 1928.—Eighteen days after fracture. X-ray: The amount of callus is regarded as abnormally slight. February 11, 1928.—Thirty-nine days after fracture. X-ray: Increase in callus formation, but still not normal. February 20, 1928.—Forty-eight days after fracture. X-ray: The callus formation is slightly increased. Presumably, there is now definite union. Experiment concluded.

A6.—Dog, medium size, black and white, long-haired male. *Operation.*—January 17, 1928, ligation of tibial artery and fracture of tibia at junction of middle and lower thirds. February 4, 1928.—Eighteen days after fracture animal died. X-ray: (After death.) The ends of the bones are rather dense. There is no visible callus formation and therefore no evidence of actual union.

A7.—Dog, black and white, short-haired female, medium size. *Operation.*—January 26, 1928, ligation of anterior tibial artery and fracture of tibia at junction of middle

and lower thirds. February 4, 1928.—Nine days after fracture. X-ray: Moderate callus formation. February 11, 1928.—Sixteen days after fracture. X-ray: There is definite increase in callus formation. February 20, 1928.—Twenty-five days after fracture. X-ray: The bones are firmly united in good position. There is more callus formation at this time than at the last examination. February 25, 1928.—Animal died.

A9.—Dog, large, black, short-haired female. *Operation.*—February 10, 1928, fracture of tibia. February 24, 1928.—Fourteen days after fracture. X-ray: Slight bowing of

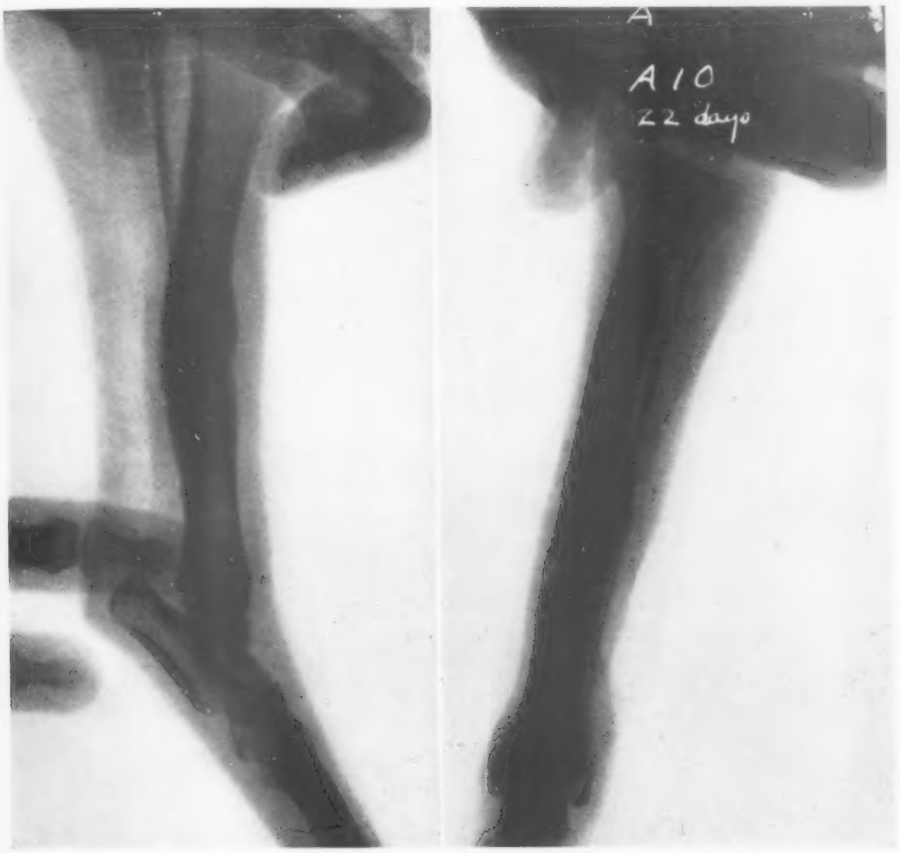


FIG. 16.—A10, twenty-two days after fracture. Firm union.

fragments. No evidence of callus formation. March 8, 1928.—Twenty-six days after fracture. X-ray: Increased density of the ends of the bone. No evidence of union. March 17, 1928.—Thirty-five days after fracture. X-ray: Considerable increase in callus formation. No union. March 29, 1928.—Forty-seven days after fracture. X-ray: Considerable callus, but no union. April 10, 1928.—Fifty-nine days after fracture. X-ray: Osseous union. Experiment concluded.

A10.—Dog, medium size, female, white with tan spots. *Operation.*—February 10, 1928, fracture of the tibia. February 24, 1928.—Fourteen days after fracture. X-ray: Moderate callus formation. March 3, 1928.—Twenty-two days after fracture. X-ray: Firm union. Experiment concluded.

A11.—Dog, brown, long-haired female, medium size. *Operation.*—February 15, 1928, ligation of anterior tibial artery and fracture of tibia. February 28, 1928. Thirteen days after fracture. X-ray: Very slight amount of callus. March 8, 1928.—Twenty-one days

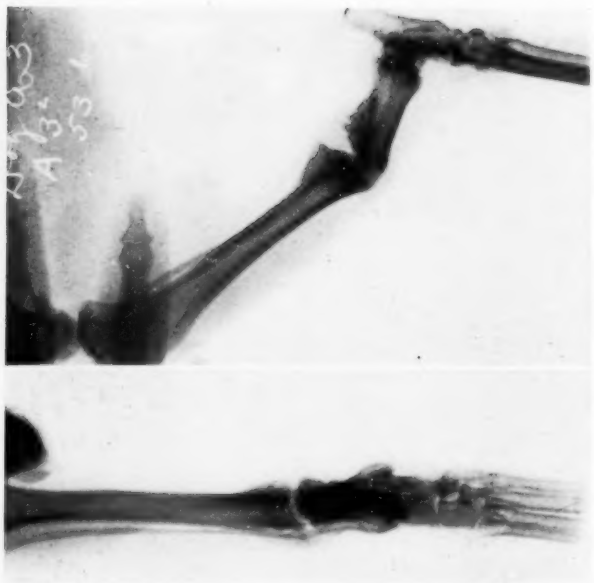

FIG. 18.—$A3^2$, fifty-three days after fracture. Probable osseous union, slight rarefaction of the opposing ends of the bone.

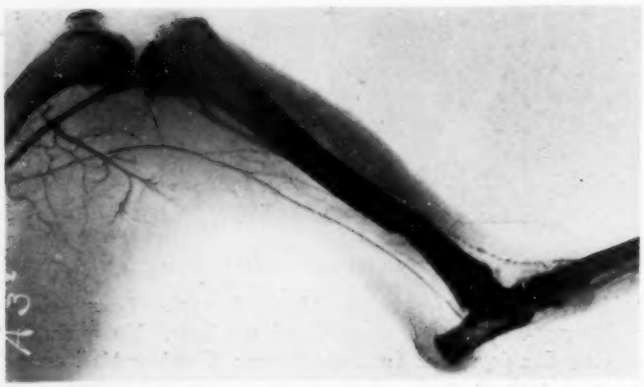

FIG. 17.—$A3^2$, original oil injection. Injection shows ligation of the anterior tibial artery. There is, however, oil in the lower portion of the anterior tibial artery, evidently due to the collateral circulation.


FIG. 19.—A4², original oil injection. The vessels are shown very distinctly. The anterior tibial and dorsalis pedis arteries are seen to be ligated and, apparently, there is no collateral circulation as evidenced by lack of oil in the vessels.


FIG. 20.—A4², sixty-one days after fracture. Moderate amount of callus, but no osseous union. Ends of the fragments are dense and rounded.

after fracture. X-ray: Evidence of external callus and, possibly, union. March 17, 1928.—Thirty days after fracture. X-ray: Fragments are united. Experiment concluded.

A12.—Dog, white and brown, long-haired male, medium size. *Operation.*—February 15, 1928, ligation of anterior tibial artery and fracture of tibia. February 28, 1928.—Thirteen days after fracture. X-ray: Slight external callus. March 8, 1928.—Twenty-one days after fracture. X-ray: There is considerable external callus and a haziness of the fracture outlines suggesting union. March 17, 1928.—Thirty days after fracture. X-ray: Fragments united in good position. Experiment concluded.

FIG. 21.—A4², eighty days after fracture. This photograph presents the typical picture of non-union.

A3².—Dog, tan and white, long-haired female, medium size. *Operation.*—June 28, 1928, ligation of anterior tibial artery and fracture of tibia. Campiodol injection of femoral artery. X-ray: Excellent injection of the vessels, showing ligation of the anterior tibial artery. There is, however, oil in the lower portion of the anterior tibial artery evidently due to collateral circulation. July 19, 1928.—Twenty-one days after fracture. X-ray: Moderate amount of external callus with bowing of the fragments. August 2, 1928.—Thirty-five days after fracture. X-ray: Callus has increased, but there is no osseous union. August 10, 1928.—Forty-three days after fracture. X-ray: No osseous union. Considerable callus. August 23, 1928.—Fifty-six days after fracture. X-ray: Probable osseous union—slight rarefaction of opposing ends of bone. Experiment concluded.

A4².—Dog, tan, short-haired female, medium size. *Operation.*—July 9, 1928, ligation of anterior tibial and dorsalis pedis arteries. Fracture of tibia and campiodol injection of femoral artery. X-ray: Injection of the vessels shows very distinctly. The anterior tibial and dorsalis pedis arteries have been ligated and apparently there is no collateral circulation as evidenced by the lack of oil in the vessels. July 31, 1928.—Twenty-two days after fracture. X-ray: Slight callus present, but no union. August 10, 1928.—Thirty-two days after fracture. X-ray: Increased callus formation, but no osseous union. August 23, 1928.—Forty-five days after fracture. X-ray: No evidence of osseous union, extensive callus formation, ends of fragments becoming rounded. September 8, 1928.—Sixty-one days after fracture. X-ray: Moderate amount of callus, but no osseous union. Ends of fragments denser and more rounded. September 17, 1928.—Seventy days after fracture. X-ray: No osseous union. September 28, 1928.—Eighty-one days after fracture. X-ray: Non-union. October 2 1928.—Eighty-seven days after fracture. Femoral artery injected with four cubic centimetres of campiodol and instantly X-rayed. X-ray: Injection shows ligation. There are several branches from the ligated proximal artery to the fracture site. October 3, 1928.—Animal died.

A9².—Dog, black, short-haired female, large size. *Operation.*—September 12, 1928, ligation of anterior tibial and dorsalis pedis arteries. Fracture of the tibia. Campiodol

FIG. 22.—$A_4^2$, final oil injection. Injection shows ligations. There are several branches from the proximal ligation to the fracture site.



FIG. 23.—$A_4^2$, isolated tibia, showing the non-union.



FIG. 24.—$A_4^2$, photograph of the specimen of tibia cut sagittally, showing the fibrous line between the fragments.

injection of the femoral artery. X-ray shows ligations of anterior tibial and dorsalis pedis arteries. October 16, 1928.—Thirty-four days after fracture. X-ray: Slight angulation—slight callus formation. October 30, 1928.—Forty-eight days after fracture. X-ray: Angulation increased, slight callus, no osseous union. November 9, 1928.—Fifty-eight days after fracture. X-ray: Callus increasing, no osseous union. November 25, 1928.—Seventy-four days after fracture. X-ray: No osseous union. December 6, 1928.—Eighty-seven days after fracture. X-ray: Fragments nearly at right angles, no osseous union. January 3, 1929.—One hundred fifteen days after fracture. X-ray: No osseous union. January 19, 1929.—One hundred thirty-one days after fracture. X-ray: No osseous union. February 1, 1929.—One hundred forty-three days after fracture. X-ray: No osseous union. March 4, 1929.—At the completion of the problem, the animal was still living with non-union, one hundred seventy-four days after fracture.

FIG. 25.—A4², low power microphotograph of specimen showing the fibrous tissue between the fragments with no osseous invasion.

A10².—Dog, white and tan, medium size. *Operation.*—October 2, 1928, ligation of dorsalis pedis and anterior tibial arteries and fracture of tibia. October 16, 1928.—Fourteen days after fracture. X-ray: Beginning external callus formation. October 30, 1928.—Twenty-eight days after fracture. X-ray: There is moderate callus formation, but no osseous union. November 9, 1928.—Thirty-eight days after fracture. X-ray: Considerable external callus, but no osseous union. December 3, 1928.—Fifty-two days after fracture. X-ray: No osseus union. December 3, 1928.—Fifty-two days after fracture. X-ray: No osseous union. December 17, 1928. Sixty-six days after fracture. X-ray: Firm osseous union. December 18, 1928.—Oil injection shows ligation of anterior tibial with anastomoses from the ligated stump to the fracture site. Experiment concluded.

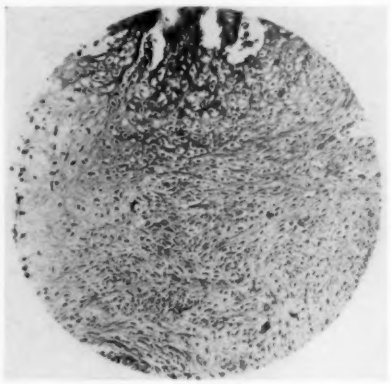

FIG. 26.—A4², high power of Figure 25, showing the fibrous tissue and a portion of the osseous tissue at the margin of the fibrous band.

A11².—Dog, brown, long-haired female, large size. *Operation.*—October 5, 1928, ligation of anterior tibial and dorsalis pedis arteries. Fracture of the tibia. Oil injection of femoral artery. X-ray: Injection shows ligations. October 16, 1928.—Eleven days after fracture. X-ray: No evidence of callus formation. October 30, 1928.—Twenty-five days after fracture. X-ray: Slight external callus formation. November 9, 1928.—Thirty-five days after fracture. X-ray: No osseous union. There is some clubbing of the fragments and slight callus formation. November 25, 1928.—Fifty days after fracture. X-ray: External callus formation increased. Ends of bone quite dense. December 6, 1928.—Sixty-three days after fracture. X-ray: Considerable callus, but no union. December 26, 1928.—Eighty-two days after fracture. X-ray: Fibula probably united, tibia ununited. January 12, 1929.—Ninety-nine days after fracture. X-ray: Moderate callus. Union appears to be taking place. January 21, 1929.—One hundred six

FIG. 27.—A10², twenty-eight days after fracture. There is moderate callus formation but no osseous union.

FIG. 28.—A10², sixty-six days after fracture, final oil injection. This photograph shows the ligations of the anterior tibial and dorsal's pedis arteries. Note the opaque material in the anterior tibial artery over the fracture site. Note also the extensive anastomoses from the proximal ligation.


FIG. 29.—A11², original oil injection. This injection shows ligations of the anterior tibial and dorsalis pedis arteries.

days after fracture. X-ray: Beginning union of tibia. January 26, 1929.—One hundred eleven days after fracture. X-ray: Tibia united. Oil injection shows extensive collateral circulation from the ligated anterior tibial artery. Experiment concluded.

A12[2].—Dog, white and brown, long-haired male, medium size. *Operation.*—October 16, 1928, fracture of the tibia. Oil injection of femoral artery. X-ray shows the anterior tibial and dorsalis arteries patent and without ligations. November 9, 1928.—Twenty-four days after fracture. X-ray: There is moderate external callus formation. November 25, 1928.—Forty days after fracture. X-ray: Excessive callus formation, but no union. December 5, 1928.—Fifty days after fracture. X-ray: Beginning union of

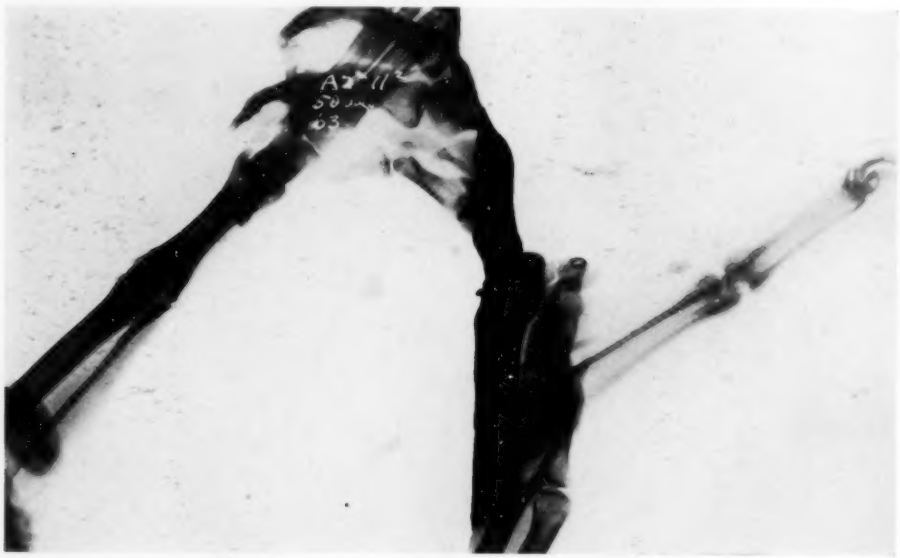

FIG. 30.—A11[2], sixty-three days after fracture. Considerable callus, but no union.

fibula. December 26, 1928.—Seventy-one days after fracture. X-ray: Fibula united, tibia ununited. January 12, 1929.—Ninety days after fracture. X-ray: No evidence of union of tibia. January 21, 1929.—Ninety-seven days after fracture. X-ray: No change since last examination. February 1, 1929.—One hundred seven days after fracture. X-ray: Tibia united. February 8, 1929.—Oil injection. X-ray: The anterior tibial artery is normally outlined with opaque solution. If this dog has had a ligation of the vessel in the foot, there has been no interruption of the blood around the site of the fracture. Experiment concluded.

B1[2].—Dog, brown, curly-haired male, large. *Operation.*—October 23, 1928, ligation of anterior tibial and dorsalis pedis arteries. Fracture of the tibia. October 25, 1928.—Oil injection. X-ray: The injection is not very satisfactory, but shows the ligation of the dorsalis pedis artery. November 16, 1928.—Twenty-four days after fracture. X-ray: Slight external callus formation. December 3, 1928.—Forty-one days after fracture. X-ray: Slight increase in callus formation. December 6, 1928.—Forty-four days after fracture. X-ray: No evidence of union. December 20, 1928.—Fifty-eight days after fracture. X-ray: Fibula united, no union of tibia. January 5, 1929.—Seventy-four days after fracture. X-ray: Tibia still ununited. January 21, 1929.—Eighty-eight days after fracture. X-ray: Tibia united. February 1, 1929.—Oil injection. X-ray: Shows ligation with extensive collateral circulation from the proximal ligation. Experiment concluded.

FIG. 31.—A11², one hundred and six days after fracture. Non-union of the tibia.


FIG. 32.—A11², one hundred and ten days, union of tibia, final oil injection showing extensive anastomosis and collateral circulation from the ligated anterior tibial artery.

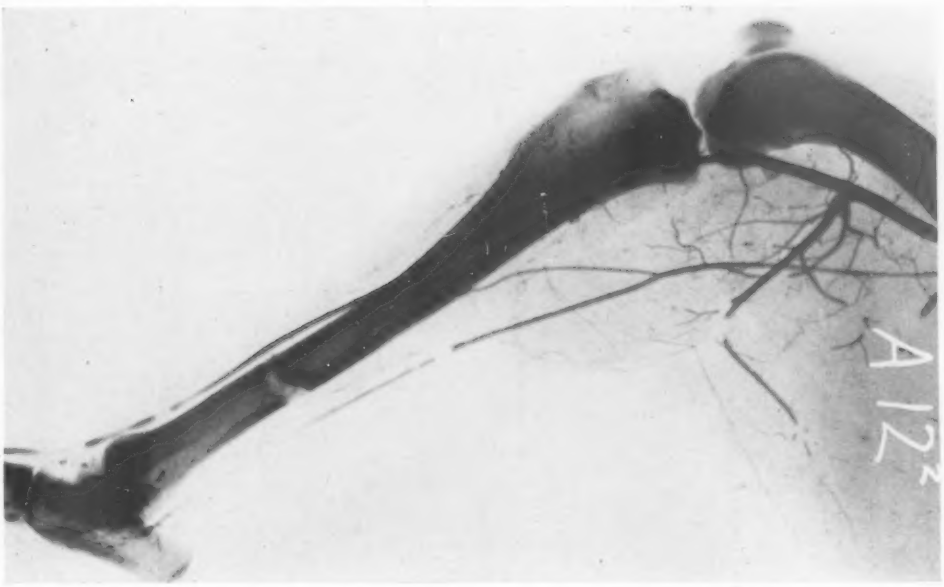


FIG. 33.—A12², original oil injection showing anterior tibial artery patent throughout.

FIG. 34.—A12², fifty days after fracture. Beginning union of fibula. No union of tibia.

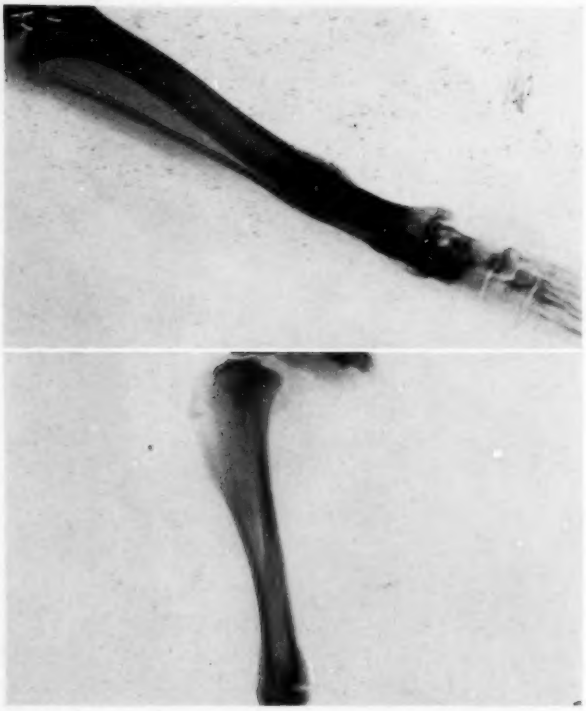

FIG. 35.—A12[2], one hundred and seven days after fracture. Tibia united.

FIG. 36.—A12², final oil injection. Anterior tibial artery patent. Some anastomosis about the fracture site.

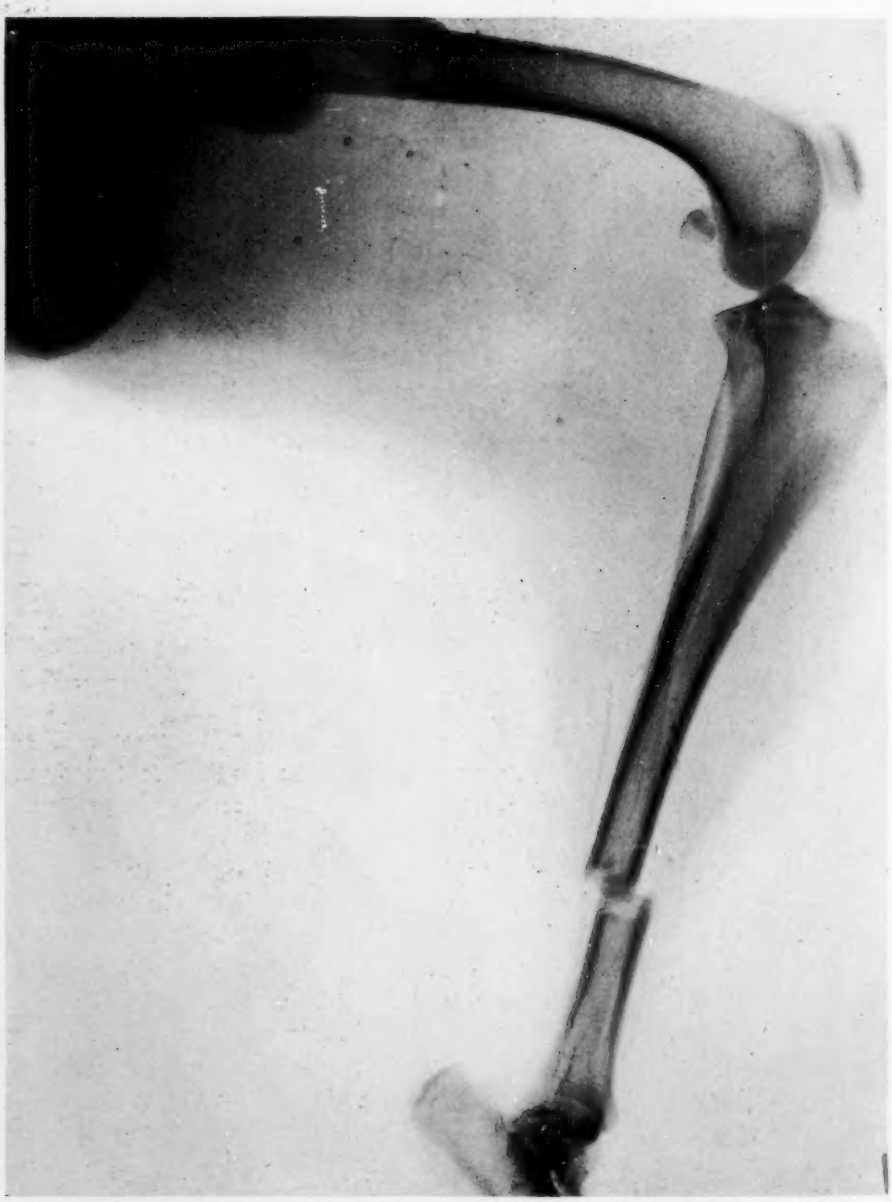

FIG. 37.—B1², original oil injection shows ligation of the dorsalis pedis artery, but the injection is not very satisfactory.

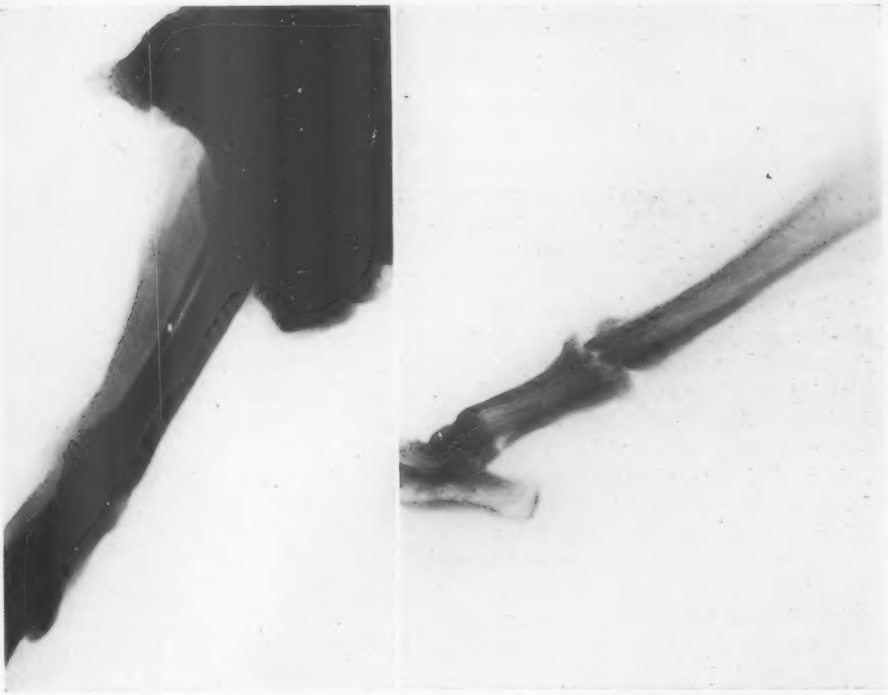

FIG. 38.—B1², forty-one days after fracture. Slight external callus formation.

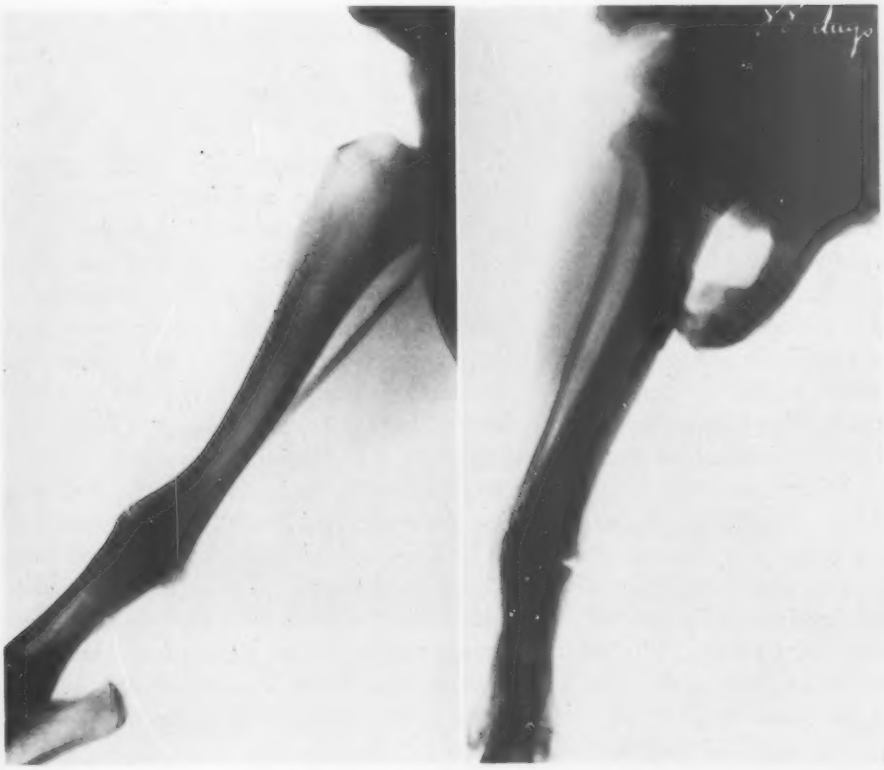

FIG. 39.—B1², eighty-eight days after fracture. Tibia united.

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DISCUSSION.—DR. ELDRIDGE L. ELIASON said that it has been supposed for years that faulty fixation, faulty approximation, and faulty blood supply were the three causes of non-union. All three may be causes, but they are relative with regard to the bone involved. The clavicle is an example of this. Here we often have faulty fixation and faulty approximation and yet very seldom is it the site of non-union. On the other hand in fractures of the lower third of the tibia in which it is extremely easy to get fixation and in which wide separation of the fragments is very unusual, we frequently find delay and non-union. The blood supply of the fragments may be, and usually is, influenced by the position and character of the fracture.

Doctor Lacey has turned his attention toward the blood supply to the exclusion of every other factor. In doing the work, he brought up the question as to whether any investigation should be done on blood calcium and blood phosphorus. He thought probably not, because of the fact that this had been done previously and because, if done, the subject should be considered from the standpoint of the individual fracture, namely, of the shaft of the humerus, the lower third of the tibia, and in some instances of fracture of the junction of the lower third of the radius. The blood supply in these cases is reduced and consequently also the local calcium and phosphorous.

FIG. 40.—B1², final oil injection shows ligation of anterior tibial and dorsalis pedis arteries with extensive collateral circulation of the ligated anterior tibial.

The speaker believes that the clinical application of this study is to the effect that we must protect the blood supply. If, for example, in fractures of the lower third of the tibia, we put on a shoe-top extension or a St. Clair skate with straps uniting across the dorsum of the foot, or if we apply a plaster case encircling the foot, the dorsalis pedis artery may be pressed upon and the already meagre blood supply be further reduced. It should make us careful to observe the blood supply of the dorsalis pedis and if there is any constriction or swelling from our dressing it should be relieved and we should apply our traction either through skeletal attachment or by means of plaster splints rather than encircling ones.

# THE EFFECT OF IODINE AND THYROID FEEDING ON THE THYROID GLAND*

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From the Laboratory of Research Surgery, University of Pennsylvania. Aided by a grant from the Harriet M. Frazier Foundation for Research in Surgery

Last year one of us (W. B. M.)[1] published the results of a series of thyroid and iodine feeding experiments. In that study our conclusions were drawn from three groups of animals. In all groups preliminary biopsy was practiced. Group I comprised animals in which ten minims of Lugol's Solution were added to the diet daily for six weeks at the end of which time biopsy was again done. After a rest period of several months, a section of the thyroid was again removed for study. Group II consisted of animals in which thyroid was given in increasing quantities until the animals exhibited symptoms of hyperthyroidism. A section of the thyroid was then removed and Lugol's Solution was given for six weeks when a third section was taken and, after a rest period of three months, a fourth section was taken. In Group III, thyroid extract was continued for the six-week period that the animals of Group II received iodine.

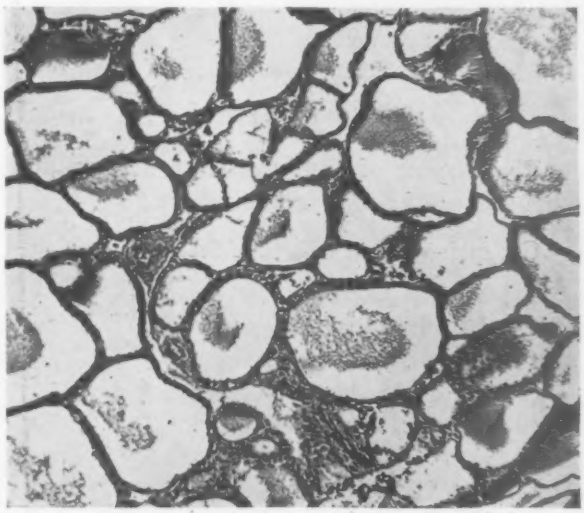

Fig. 1.—Low power normal thyroid gland of dog.

From this study we were led to agree with the conclusions of Marine that iodine stimulated the cells of the thyroid acini to produce colloid. The newly-formed colloid caused compression of the cells. The effect of iodine (Lugol's Solution) and thyroid extract on the experimental animal were apparently not distinguishable. The prolonged administration of iodine or iodine and thyroid extract apparently resulted in a microscopic picture of thyroid exhaustion.

* Read before the Philadelphia Academy of Surgery, March 4, 1929.

These studies led us to disagree with Plummer's theory on the effect of iodine on the course of hyperthyroidism. While Plummer believes that the toxic goitre probably secretes a deiodized thyroxin and that iodine exerts its beneficial effect by supplying the iodine radical to this substance, we have felt and are more convinced that the beneficent effect of this drug is due to its effect on the seat of production of the thyrotoxic substance. We believe that the investigations of Kunde [2] and Badger and Sturgis [3] have proven that iodine has no effect on the circulating thyrotoxic substance. Further, Harrington has synthetized thyroxin with incomplete saturation of iodine and Gaddum,[4] in studying these partially deiodized thyroxins, found that as a whole they did not exhibit a similar effect on the metabolism.

It was decided, because of some variation in the typical iodine effect in some animals of the first series, to reproduce the experiment, from a slightly different angle and with more careful attention to the feeding of the animals and the keeping of different groups in separate rooms. It was felt that with more careful control of experimental conditions, the histological picture of the specimens removed would probably not show the variations observed in a similar rotation of drug administration.

## PROBLEM AND METHOD

The purpose of the experiment was to observe the histological effect in three groups of animals.

Group I.—Effect of iodine feeding.

(*a*) Normal gland.
(*b*) Histology after twelve weeks of iodine feeding.
(*c*) Histology at end of rest period of nine weeks.
(*d*) Histology after thyroid feeding for twelve weeks.
(*e*) Rest period of nine weeks.

Group II.—Effect of iodine and thyroid feeding.

(*a*) Histology of normal gland.
(*b*) Histology after twelve weeks' iodine feeding.
(*c*) Histology after a rest period of nine weeks.
(*d*) Histology after thyroid feeding for twelve weeks.
(*e*) Rest period of nine weeks.

Group III.—Final effect of iodine feeding.

(*a*) Histology of normal gland.
(*b*) Histology after twelve weeks of iodine feeding.
(*c*) Rest period for indefinite period, during which time biopsy should be taken to observe the final effect of the iodine feeding.

The feeding experiments were begun in April, 1928, and the work was continued until February, 1929. While the animals in Group II were receiving thyroid extract, they exhibited certain symptoms of hyperthyroidism, that

is, a loss of weight, tachycardia, and a moderate diarrhœa. No attempt was made to study the basal rate.

All biopsies were removed under strictly aseptic precautions under ether anæsthesia. In order not to confuse the microscopic picture, the sections were removed from first one lobe and then the other, and from opposite poles, when the same lobe was operated on subsequently. This we felt would permit of sections for study in which the trauma of a previous operation could be avoided.

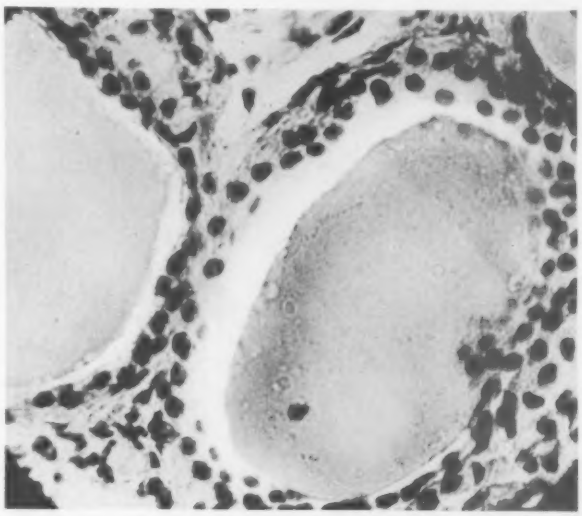

FIG. 2.—High power normal thyroid gland of dog.

*Histological Studies.*—The microscopic picture of the sections removed from the normal animals before feeding are practically the same. The acini vary in size and in the amount of colloid they contain. The cells lining the acini are of a cuboidal type with large dark-staining nuclei. There are here and there between the acini a moderate number of interstitial cells. (Figs. 1 and 2.)

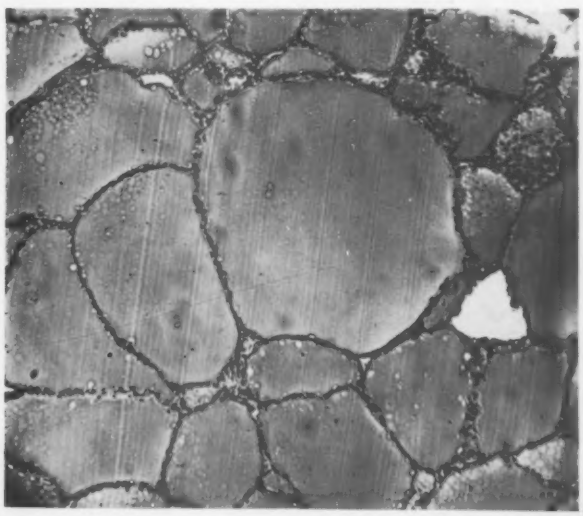

FIG. 3.—Low power of thyroid gland of dog after twelve weeks of thyroid feeding.

The typical iodine effect was obtained in every animal. The acini are now distended with colloid. The cells are flattened and elongated. The cytoplasm seems to have disappeared to a large extent and the flattened nuclei appear to form a limiting membrane from the next acinus. There is a marked reduction in the number of interstitial cells. (Figs. 3 and 4.) After the first rest period the histologic picture varied somewhat. In some sections the cells became cuboidal again, the acini were not as distended and the interstitial cells increased. In others, the iodine effect seemed to have continued, and in one to have progressed, while in another

(N83) the picture was that of early exhaustion atrophy in small areas, while the typical iodine effect persisted in others.

After the second period of iodine feeding we did not observe the same iodine effect as after the first twelve weeks of iodine feeding. The acini are moderately distended with colloid. Some of the lining cells of the acini are flattened while others are cuboidal, but as a whole, the cell markings are not as distinct. There was again a decrease in the interstitial cells. (Fig. 5.)

FIG. 4.—High power of thyroid gland of dog after twelve weeks of thyroid feeding.

The sections removed from the dogs after twelve weeks of thyroid feeding following iodine and rest were very interesting. In these we find moderate distension of the acinus with colloid, but not sufficient to produce the typical iodine effect. There is considerable variation in their size. In some fields, however, the cell lining has ruptured and the nuclei stain poorly. In other parts of the same field the cells still show some evidence of the flattening produced by the previous iodine administration and which did not disappear during the rest period. Throughout the section, however, are areas showing some proliferation of the interstitial cells. (Figs. 6 and 7.)

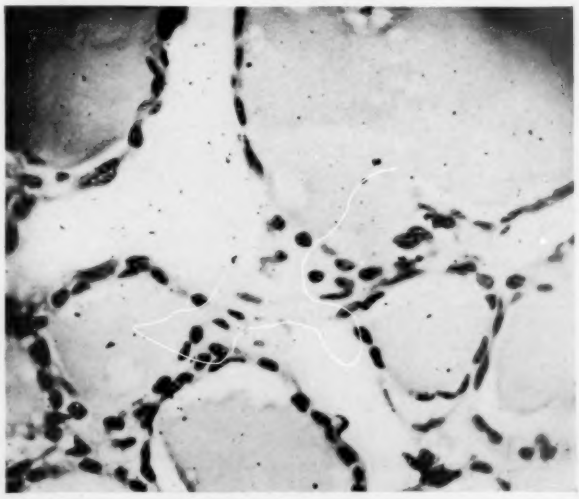

FIG. 5.—High power of thyroid of dog after second period of iodine feeding.

The late sections taken from all the animals were exceedingly interesting. In the animals given iodine either for both of the feeding periods or for one feeding period followed by complete rest, the sections show varying degrees of thyroid exhaustion atrophy. In one dog (N87) given only the one period of iodine feeding, the

picture at the end of thirty-three weeks showed complete disorganization of the glandular structure. (Fig. 8.) The picture looks very much like one would expect to see following a thyroiditis. In some places proliferation of fibrous tissue has taken place. The picture is nearly identical with that of Figure 9, taken from a section of human thyroid. The patient, who had exophthalmic goitre, had been given iodine over a number of months. It is extremely interesting to note the recovery which occurred in dog N87 during the second rest period. (Fig. 10.) Here one sees an attempt toward the reformation of acini. Areas of atrophy adjoin fairly-well developed acini with colloid, while amongst both one can observe cells taking on an acinar arrangement, but in which no colloid is present. The blood supply is markedly increased. This attempt at a return to normal is indeed striking. In other animals the histologic picture showed varying degrees of involution with imperfectly formed acini containing free epithelial cells.

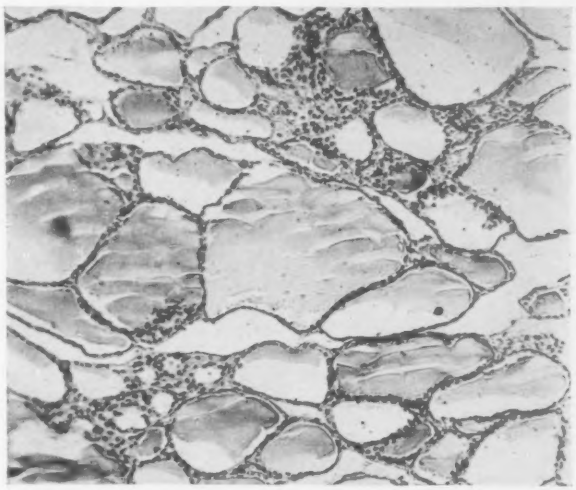

FIG. 6.—Low power of thyroid gland of dog after feeding desiccated thyroid.

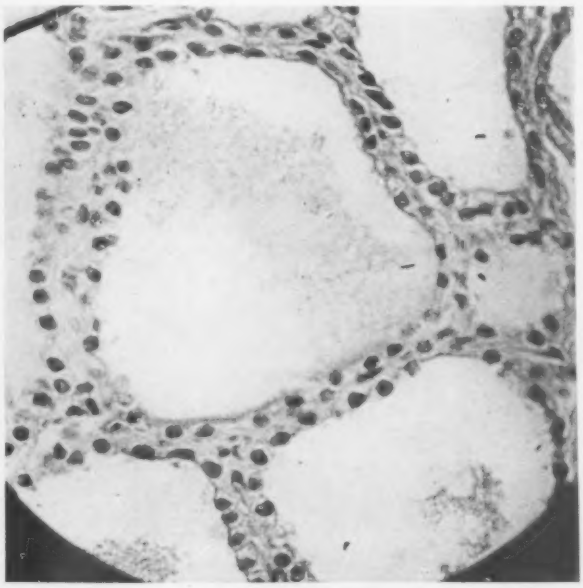

FIG. 7.—High power of thyroid gland of dog after feeding desiccated thyroid.

The sections removed from the animals after a rest period subsequent to thyroid feeding showed a marked proliferation of the interstitial cells, with considerable reduction in the size of the acini. (Fig. 11.) This increase in the interstitial cells is much more marked than was observed immediately after the thyroid feeding period.

*Discussion.*—There would seem to be little doubt as to the effect of iodine,

either on the normal or hyperplastic gland. On the normal gland of the dog it causes an increase in colloid formation with a decrease in the interstitial tissue and a striking flattening of the acinar cells. Marine and Williams [5] and Marine and Lenhart [6] have demonstrated that the amount of stainable colloid varied with the iodine content of the gland. Marine further demonstrated that nearly 5 per cent. of a single dose of potassium iodide given to a dog was stored in the gland within a period of two hours after its administration. The effect of desiccated thyroid is not nearly so striking and after these feedings we observed an increase rather than a decrease in the interstitial tissue. The exhaustion atrophy which was observed in varying degrees after iodine administration appears very similar to the picture one would expect in cases of thyroiditis. The striking thing is the ability of the gland to again take on a somewhat normal picture after a rest period.

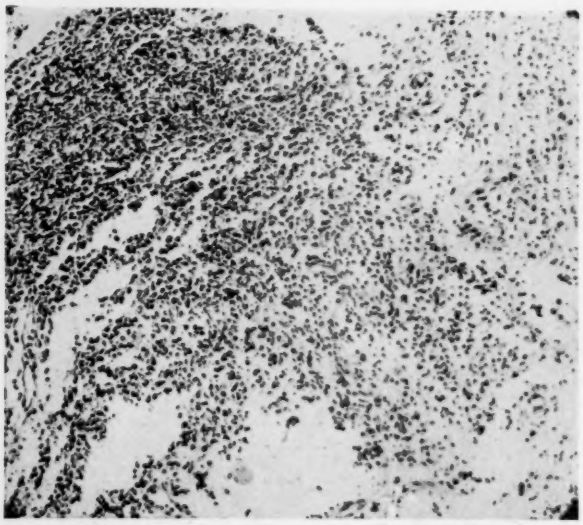

FIG. 8.—Exhaustion of thyroid gland of dog after feeding.

Marine [7] states that "a thyroid that has less than 0.1 per cent. of iodine per gram of dry gland cannot be normal, and a gland that has had continuously a content greater than this amount cannot be abnormal anatomically". We have not estimated the iodine content of the dried gland of the dogs fed iodine, but certainly the specimens demonstrate anatomic variations from the normal. Whether these variations are the result of a thyroiditis we cannot definitely state. The sections demonstrate the ability of the thyroid cells of these animals to return to normal when given physiological rest.

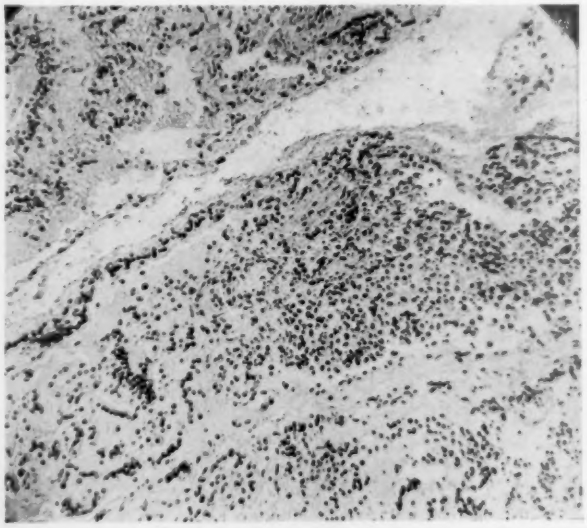

FIG. 9.—Exhaustion in the human toxic goitre after prolonged iodine administration.

The slides from the biopsies after thyroid feeding are somewhat difficult to explain. The partial iodine effect observed in some slides could perhaps be due to the iodine content of the desiccated thyroid gland fed the animals. The sections taken from the animals subsequent to a rest period after thyroid feeding clearly demonstrate hypertrophy. The repeated biopsies may have called forth a compensatory hypertrophy and this may explain why under rest the hypertrophy occurred, while during thyroid feeding it failed to occur. Marine has shown that desiccated thyroid will protect against thyroid regeneration. However, Marine[8] and Loeb[9] differ on the effect of iodine on regeneration. Marine believes that regeneration will not occur if not more than three-fourths of the dog's thyroid is removed and iodine is administered. Loeb[9] showed that after subtotal thyroidectomy in the dog, iodine not only failed to retard regeneration, but actually hastened it. It may be that Loeb[9] removed more than three-fourths of the gland. Marine[8] states that if more than three-fourths of the gland is removed iodine will not protect against regeneration.

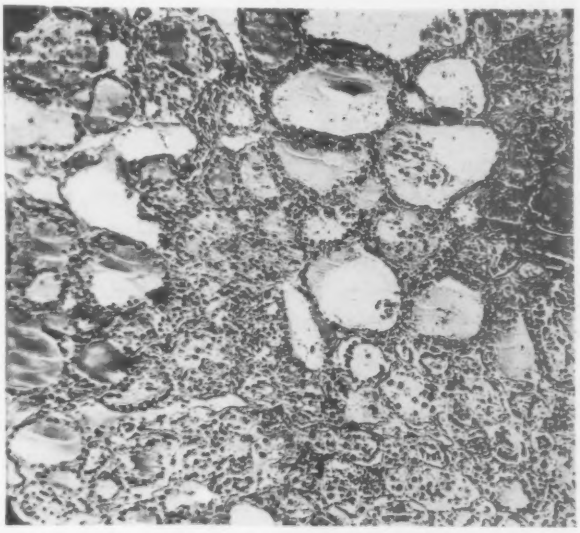

FIG. 10.—Low power. Regeneration of thyroid gland of dog during the period of rest following exhaustion.

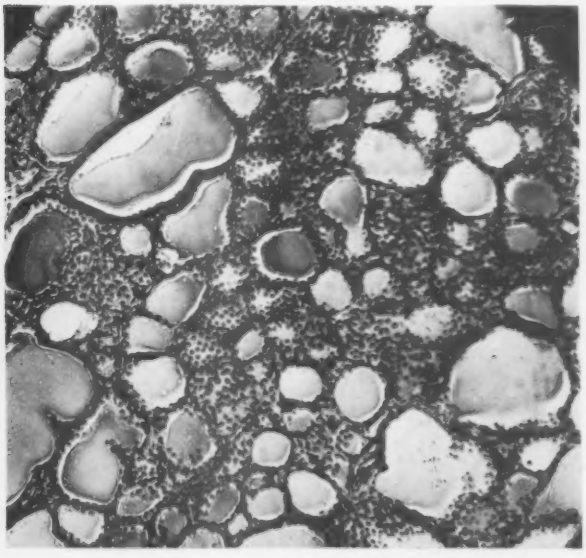

FIG. 11.—Low power at conclusion of rest period following thyroid feeding.

The effect of iodine on the hyperplastic thyroid gland of the human must be due to the ability of iodine to restore the gland temporarily to more normal function. The increased formation of colloid, compression of the cells and decrease of blood supply are factors that suggest mechanical reduction of thyroid activity. It is reasonable to assume

that the distorted, compressed cells are incapable of secreting their usual amount of thyrotoxic substance, with consequent clinical improvement.

It is well known that the clinical improvement from iodine ingestion is often only temporary. This may be explained in various ways. The cells may readjust themselves and gradually regain their ability to secrete; or, as the cells become exhausted, they may also become incapable of producing sufficient colloid to maintain mechanical compression and thus they may release themselves. It is a frequent observation to find a microscopic picture of exhaustion in a toxic goitre removed from a patient after prolonged iodine ingestion—the patient at the time of operation no longer being capable of being beneficially effected by the iodine. The microscopy of these glands, however, would indicate that the gland was inactive. There may be some chemical explanation to explain the beneficent effect of iodine, but we feel certain that Plummer's theory is not the correct one.

## CONCLUSIONS

1. We have confirmed the observations of Marine and of ourselves that ingestion of iodine increases the amount of colloid in the thyroid gland.

2. Colloid retention compresses the cells lining the acini.

3. A stage of exhaustion may occur in the thyroid of the normal dog after prolonged iodine administration, which may be followed by a state of partial recovery during a rest period.

4. A stage of exhaustion occurs in the gland of the human with hyperthyroidism who has taken iodine for a prolonged period. The clinical status of the patient is not proportionate to the histological interpretation.

5. In this study we were unable to confirm our previous findings that the effect of desiccated thyroid was similar to the effect of iodine on the gland of the normal dog.

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# EFFECT OF ABDOMINAL THERMAL APPLICATIONS ON THE INTRAPERITONEAL TEMPERATURE *

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Aided by a grant from the Harriet M. Frazier Fund for Research in Surgery

Thermal applications have been used extensively as therapeutic agents since ancient times. There can be no doubt as to their efficacy in the treatment of a variety of clinical conditions. There is, however, some question as to just how they act, especially when applied to the treatment of intra-abdominal lesions. A good deal of evidence has been brought forward to show that heat and cold penetrate fairly readily through the tissues, but there is surprisingly little information in the literature as to the effects of hot and cold applications on the intraperitoneal temperature.

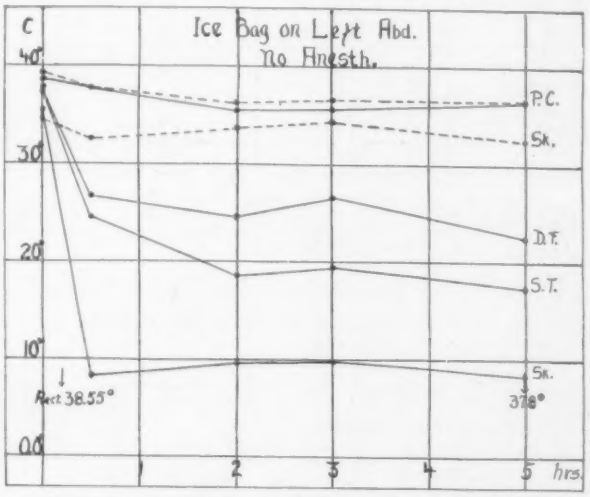


Chart I.—Sk., Skin temperature. S. T., Superficial Tissue temperature. D. T., Deep Tissue temperature. P. C., Peritoneal Cavity temperature. Rect., Rectal temperature. Heavy lines, Left abdomen (side on which ice bag was applied). Dotted lines, Right abdomen.

Exclusive of the direct effect of abdominal thermal applications on the intraperitoneal temperature, they are of definite use in other ways. The psychic effect on the patient is always beneficial. He knows something is being done for him. There is ample clinical evidence that cold acts as a local anæsthetic agent, frequently relieving pain. Heat applied to the abdominal wall may relieve abdominal cramps and act as a soothing agent, but its direct effect on the intraperitoneal lesion is a debatable point. Many surgeons believe it causes a reflex effect within the abdomen. There is some indirect evidence in support of this. Goldschmidt and Light [1] have shown that, when one arm was surrounded by water of a definite temperature range, reflex responses were found in other superficial areas. At the extremes of temperature the reflex responses were slight. Von Friedrich and Bokor [2] reported that an ice bag placed on the epigastrium caused increased peristalsis. The same effect

* Read before the Philadelphia Academy of Surgery, March 4, 1929.

is obtained when cold is applied to other areas of the skin. These investigators conclude that the effect must be due to a reflex mechanism.

There is a divergence of opinion as to whether heat or cold should be used in certain abdominal conditions. In appendicitis, for example, practically everyone uses cold. In pelvic inflammatory diseases, heat is more frequently applied. Some surgeons believe that cold is indicated in peritonitis, while others believe that heat is preferable.

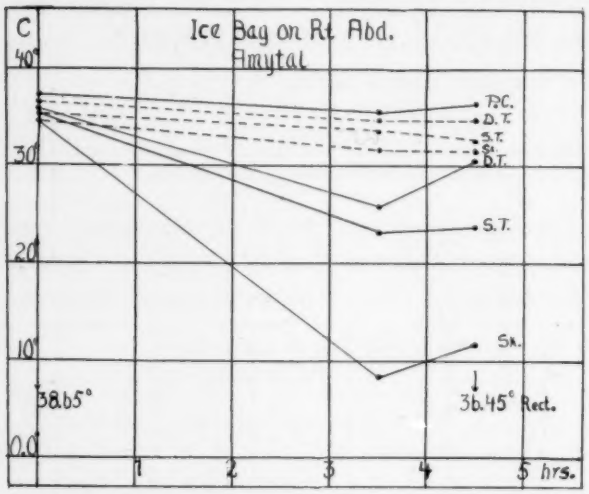


CHART II.—Sk., Skin temperature. S. T., Superficial Tissue temperature. D. T., Deep Tissue temperature. P. C., Peritoneal Cavity temperature. Rect., Rectal temperature. Heavy lines, Right abdomen. Dotted lines, Left abdomen.

Leyton and Sherrington [3] demonstrated that an ice bag or hot-water bottle applied to the skull might change the intradural temperature through a range of 5° or 6° C. Zondek [4] made observations on the thighs of human subjects, using a fine mercury thermometer introduced through a trocar. He realized there were several sources of error in his method and made corrections for some of them. In one experiment he introduced the thermometer obliquely into the thigh for a distance of seven centimetres so that its point was about five centimetres deep. An ice bag applied for one hour over this area lowered the skin temperature from 34.8° to 7° C. and the deep muscle temperature from 37.1° to 36.3° C. MacLeod and his co-workers,[5] working on rabbits and using a thermocouple within a hypodermic needle, were able to show a rise of 4.07° C. in muscle temperature at a

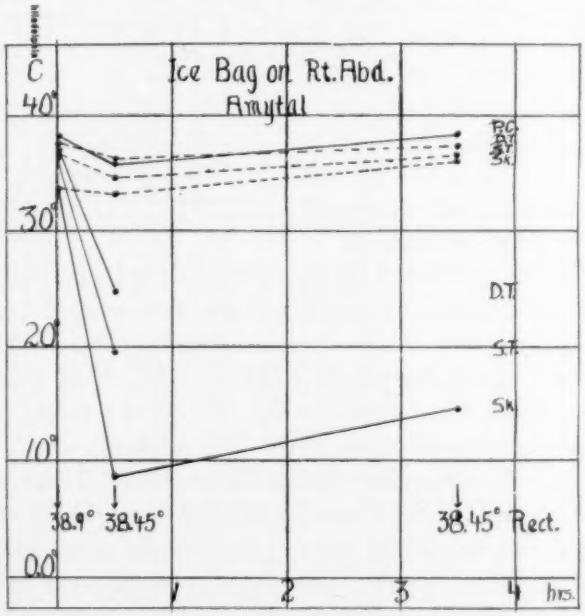


CHART III.—Sk., Skin temperature. S. T., Superficial Tissue temperature. D. T., Deep Tissue temperature. P. C., Peritoneal Cavity temperature. Rect., Rectal temperature. Heavy lines, Right abdomen. Dotted lines, Left abdomen.

depth of seventeen millimetres after the application of heat. Stengel and Hopkins [6] passed a thermocouple into the stomach through a duodenal tube. Ice bags applied over the gastric area produced a drop of 1° C. in the course of forty-five minutes, while hot-water bottles had little effect on the intragastric temperature. Zondek [4] introduced his fine thermometer, described above, into the psoas muscle just posterior to the peritoneum. He found that the application of an ice bag over the hypogastrium for two hours produced a drop of 4.5° C. and assumed that this was related to the intraperitoneal temperature. Using an electric pad as their hot applicator, MacLeod and his co-workers [5] found that the temperature just inside the peritoneal cavity rose 4° C. This corresponds almost exactly to the rise they found in muscle temperature. The thermocouple was introduced into the abdominal cavity through a hypodermic needle.

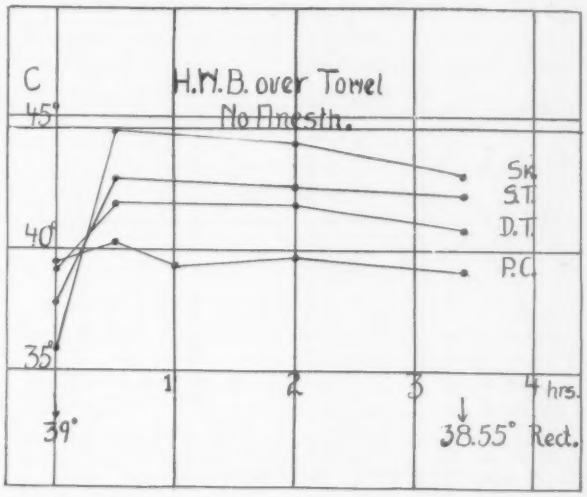


CHART IV.—Sk., Skin temperature. S. T., Superficial Tissue temperature. D. T., Deep Tissue temperature. P. C., Peritoneal Cavity temperature. Rect., Rectal temperature.

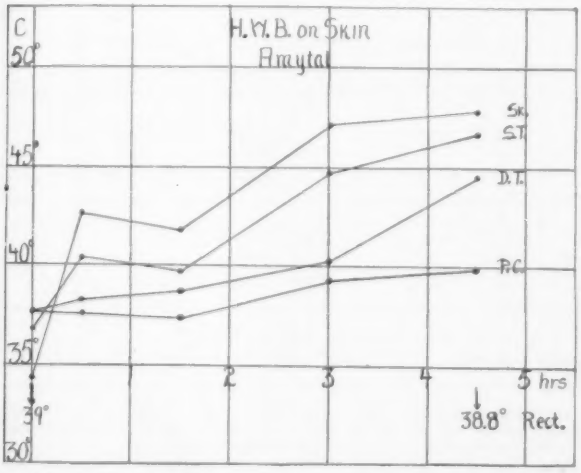


CHART V.—Sk., Skin temperature. S. T., Superficial Tissue temperature. D. T., Deep Tissue temperature. P. C., Peritoneal Cavity temperature. Rect., Rectal temperature.

*Method.*—The temperature readings recorded in the observations below, unless otherwise noted, were made with the thermo-electric apparatus designed by H. C. Bazett and B. McGlone [7] of the Department of Physiology, University of Pennsylvania, to both of whom I am indebted for much advice and encouragement. Briefly, it consists of two thermocouples, a constant temperature bath, and a galvanometer. Constantan and iron were used as the thermo-elements for the thermocouples. For deep temperatures a thermocouple of needle type was used consisting of steel tubing through which a properly insulated constantan wire (0.127 millimetre

diameter) was threaded. The diameter of the needle in most of the experiments was 0.46 millimetres; in the last three series of observations it was 0.51 millimetres in diameter.

The observations were made on dogs. The animal was strapped to a table and allowed to lie for some time, usually thirty minutes to one hour, before the experiment was started. The anæsthetic, when one was used, consisted of sodium amytal (sodium iso-amyl-ethyl-barbiturate) given intraperitoneally, fifty milligrams per kilo. The hair on the abdomen was usually so scanty that shaving was unnecessary, except in a few instances. Room conditions were kept fairly constant. Readings were made as nearly as possible at the same points. In two of the experiments in which the needle was kept continuously in the abdomen, the needle was introduced into the peritoneal cavity through the lateral abdominal wall, several centimetres distant from the thermal applicator. Otherwise, the applicator was removed to take readings beneath it. Readings of superficial tissues were taken by the introduction of the needle laterally just beneath the skin for a distance of two centimetres. The skin was frequently nicked to allow easier entrance of the needle. In the deep tissue observations, the needle was introduced in a similar manner beneath the deep fascia, usually in the rectus muscle. Peritoneal temperatures were taken by piercing the abdominal wall almost vertically. Once the needle was within the peritoneal cavity, it apparently made little difference to what depth it was introduced. The usual depth of the needle was three to five centimetres from the skin. The cold applicator consisted of ice blocks within a surgeon's rubber glove, making an ice bag of 6 x 12 cm. For

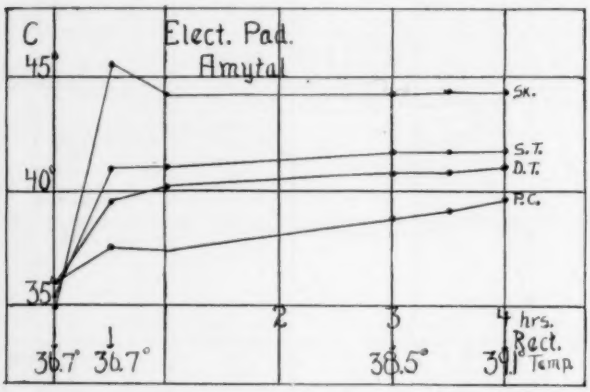


CHART VI.—Sk., Skin temperature. S. T., Superficial Tissue temperature. D. T., Deep Tissue temperature. P. C., Peritoneal Cavity temperature. Rect., Rectal temperature.

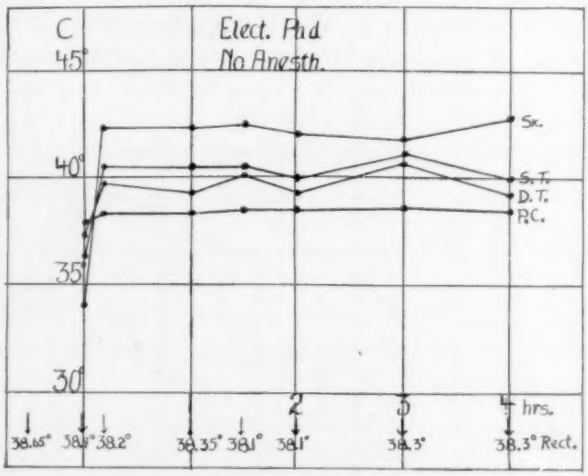


CHART VII.—Sk., Skin temperature. S. T., Superficial Tissue temperature. D. T., Deep Tissue temperature. P. C., Peritoneal Cavity temperature. Rect., Rectal temperature.

a hot applicator either an ordinary hot-water bottle was used, or an electric pad, 10 x 45 cm. doubled so that the heating surface was 10 x 22 cm.

All the rectal temperatures were taken with an ordinary clinical rectal thermometer.

## OBSERVATIONS

Table I shows intraperitoneal temperatures on a control animal with and without anæsthesia. It will be noted that there was a variation of 0.6° C. in the intraperitoneal temperature, the highest readings occurring just after the dog had voided.

TABLE I

*Dog on table fifteen minutes; abdomen not shaved; needle in abdominal cavity continuously; room temperature—25°C.; no thermal application.*

| Time P.M. | Temperature P. C. Right ° C. | Surface Temperature ° C. | Rectal Temperature ° C. | Remarks |
|---|---|---|---|---|
| 2:00 | | | 38.85 | |
| 2:05 | | 36.4 Rt. abd. | | |
| | | 36.4 Lt. " | | |
| 2:08 | 38.3 | | | |
| 2:22 | 38.8 | | | Voided |
| 2:27 | 38.8 | | | Voided |
| 2:32 | 38.6 | | | |
| 2:37 | 38.4 | | | |
| 2:42 | 38.6 | | | |
| 2:53 | 38.6 | | | |
| 3:00 | Sodium amytal—500 mgs. intraperitoneally. | | | |
| 3:40 | 38.4 | | | |
| 4:00 | 38.7 | | 38.35 | |

P. C. = peritoneal cavity.

In Table II are shown intraperitoneal temperature readings taken at frequent intervals during the application of an ice bag for one hour. This animal had no anæsthetic. The surface temperature dropped markedly and quickly from 38.8° to 8° C., while intraperitoneally there was a drop of only 0.7 of a degree during an hour.

TABLE II

*Small area on abdomen shaved; needle in abdominal cavity continuously; room temperature—24°–25° C.; ice bag on right abdomen.*

| Time P.M. | Temperature P. C. Right ° C. | Surface Temperature ° C. | Tissue Temperature ° C. |
|---|---|---|---|
| 4:00 | 38.5 | 35.8 Rt. | |
| | | 24.8 Lt. | |
| 4:05 | Ice bag applied—no anæsthetic | | |
| 4:06 | 38.5 | | |
| 4:08 | 38.4 | | |
| 4:12 | 38.4 | 8.0 Rt. | |
| 4:15 | | 34.5 Lt. | |
| 4:19 | 38.4 | | |
| 4:26 | 38.4 | | |
| 4:31 | 38.3 | | |
| 4:36 | 37.7 | | |
| 4:41 | 37.7 | | |
| 4:45 | 37.8 | | |
| 4:50 | 37.8 | | |
| 5:05 | 37.8 | | 19.5 Rt. |

P. C. = peritoneal cavity.

Table III gives observations made on the same dog over a period of five hours. A fall of 2.5° C. occurred within the abdomen. This was the greatest drop in temperature observed in any of the experiments. The rectal temperature fell only 0.75° C. These results are shown graphically in Chart I.

TABLE III

*Dog on table twenty minutes; small area on abdomen shaved; room temperature—24°C.; ice bag on left abdomen; no anæsthesia.*

| | | Control °C. | Thirty minutes °C. | Two hours °C. | Three hours °C. | Five hours °C. |
|---|---|---|---|---|---|---|
| Surf. | Rt. | 34.6 | 32.4 | 33.7 | 34.1 | 32.2 |
| | Lt. | 35.3 | 8.2 | 9.7 | 9.9 | 8.3 |
| Sup. Tiss. | Rt. | 37.8 | 35.7 | 31.6 | 31.8 | 32.0 |
| | Lt. | 37.1 | 24.6 | 18.7 | 19.3 | 17.2 |
| Deep Tiss. | Rt. | 37.8 | | 33.8 | 33.7 | 34.2 |
| | Lt. | 37.1 | 26.9 | 24.8 | 26.7 | 22.5 |
| P. C. | Rt. | 39.1 | 37.9 | 36.2 | 36.8 | 36.5 |
| | Lt. | 38.6 | 37.9 | 35.5 | 35.7 | 36.5 |
| Rectal Temp. | | 38.55 | | | | 37.8 |

P. C. = peritoneal cavity.

In another experiment the animal was given sodium amytal as an anæsthetic thirty minutes before the beginning of observations. The rectal temperature fell 2.2° C. in four and one-half hours. The peritoneal cavity temperature dropped only 1.1° C. after the ice bag had been applied steadily for the same length of time. The findings are shown in Table IV and Chart II.

TABLE IV

*Sodium amytal, 575 milligrams intraperitoneally thirty minutes before beginning of experiment; abdomen not shaved; room temperature—22.1°C.; ice bag on right abdomen.*

| | | Control °C. | Three and one-half hours °C. | Four and one-half hours °C. |
|---|---|---|---|---|
| Surf. | Rt. | 34.6 | 8.3 | 11.8 |
| | Lt. | 34.5 | 31.5 | 31.4 |
| Sup. Tiss. | Rt. | 35.2 | 23.0 | 23.7 |
| | Lt. | 35.1 | 33.4 | 32.5 |
| Deep Tiss. | Rt. | 35.9 | 25.9 | 30.3 |
| | Lt. | 36.5 | 34.7 | 34.7 |
| P. C. | Rt.+ | 37.2 | 35.4 | 36.1 |
| | Lt.+ | 37.0 | 35.4 | 36.5 |
| | Mid. | 37.1 | 35.7 | 36.1 |
| Rectal | | 38.65 | | 36.45 |

P. C. = peritoneal cavity.

Table V and Chart III show findings when the control readings were taken before the administration of the anæsthetic. Thirty minutes after the anæsthetic was given and the ice bag applied, the peritoneal temperature was found 2.4° C. below the original reading. Three hours later, however, when the dog was recovering from the effects of the anæsthetic, the peritoneal temperature had returned to its original level although the ice bag had been applied continuously to the abdomen.

TABLE V

*Sodium amytal, 500 milligrams intraperitoneally; abdomen not shaved; room temperature—24°C.; ice bag on right abdomen.*

| | | Control before amytal ° C. | Thirty minutes after amytal and cold applied ° C. | Three and one-half hours ° C. |
|---|---|---|---|---|
| Surf. | Rt. | 33.8 | 8.9 | 14.7 |
| | Lt. | 33.5 | 33.1 | 36.0 |
| Sup. Tiss. | Rt. | 36.1 | 19.6 | |
| | Lt. | 36.8 | 34.7 | 36.7 |
| Deep Tiss. | Rt. | 37.0 | 24.9 | |
| | Lt. | 37.6 | 36.1 | 37.3 |
| P. C. | Rt. | 38.1 | 35.7 | 38.3 |
| | Lt. | 38.1 | 36.1 | 38.3 |
| Rectal | | 38.4 | 38.45 | 38.15 |

P. C. = peritoneal cavity.

The hot-water bottle made an unsatisfactory heat applicator since it lost heat rapidly, necessitating frequent changes of the water. Table VI and Chart IV show results when the hot-water bottle was applied over a towel, as is usually done clinically. The water in the bottle was kept as nearly as possible to a temperature of 55° C., but probably varied from 50° to 60° C. Observations taken with a mercury thermometer between the towel and bottle gave readings from 44° to 54° C., and between the skin and towel, 40° to 50° C. The dog's skin was slightly burned toward the end of the experiment.

TABLE VI

*No anæsthesia; abdomen not shaved; room temperature—25.9°C.; hot-water bottle over towel, left abdomen.*

| | | Control ° C. | Thirty minutes ° C. | One hour | Two hours ° C. | Three hours twenty-five minutes |
|---|---|---|---|---|---|---|
| Surf. | Rt. | 35.6 | 44.4 | | 38.7 | |
| | Lt. | 35.9 | 44.9 | | 44.4 | 43. |
| Sup. Tiss. | Rt. | 38.4 | 42.0 | | 39.1 | 38.6 |
| | Lt. | 37.7 | 42.9 | | 42.5 | 42.2 |
| Deep Tiss. | Rt. | 38.6 | 40.9 | | 39.0 | 38.5 |
| | Lt. | 38.6 | 41.9 | | 41.8 | 40.8 |
| P. C. | Rt. | 39.2 | 39.6 | 38.8 | 39.0 | 38.5 |
| | Lt. | 39.3 | 40.3 | 39.2 | 39.6 | 39.0 |
| Rectal | | 39.0 | | | | 38.55 |

P. C. = peritoneal cavity.

Table VII and Chart V give findings after the application of a very hot water bottle with the animal under anæsthesia. The water in the hot-water bottle and skin was usually 55° C. taken with a mercury thermometer. No towel was used. The dog's

skin was badly burned. Under these conditions a rise of 2.3° to 2.5° C. was produced intraperitoneally.

TABLE VII

*Sodium amytal, 600 milligrams intraperitoneally; abdomen not shaved; room temperature—23°–24° C.; hot-water bottle on skin of left abdomen.*

| | | Control ° C. | Thirty minutes ° C. | One and one-half hours ° C. | Three hours ° C. | Four and one-half hours ° C. |
|---|---|---|---|---|---|---|
| Surf. | Rt. | 34.4 | 41.3 | 40.4 | 47++ | 47++ |
| | Lt. | 34.4 | 42.6 | 41.8 | 47++ | 47++ |
| Sup. Tiss. | Rt. | 35.4 | 39.5 | 38.6 | 40.8 | 41.6 |
| | Lt. | 36.7 | 40.4 | 39.6 | 44.8 | 46.6 |
| Deep Tiss. | Rt. | 36.2 | 38.6 | 38.1 | 39.5 | 41.2 |
| | Lt. | 37.6 | 38.3 | 38.7 | 40.2 | 44.5 |
| P. C. | Rt. | 37.4 | 37.5 | 37.4 | 38.7 | 40.1 |
| | Lt. | 37.6 | 37.5 | 37.4 | 39.3 | 39.9 |
| | Mid. | | | 37.4 | 39.3 | 40.1 |
| Rectal | | 39.0 | | | | 38.8 |

P. C. = peritoneal cavity.

An electric pad of the type previously described was used as the heat applicator in the next experiment. This animal had been under anæsthesia for one and one-half hours before the experiment started. The rectal temperature was 36.7° C., obviously subnormal. It rose to 39.1° C., during the four hours under observation. This factor is important in considering the fairly marked rise in the peritoneal temperature as shown in Table VIII and Chart VI. The rise was 3.5° C., the greatest temperature change found in these observations. The dog's skin was not blistered. The temperature between the skin and pad varied from 44° to 48° C., although between the folds of the pad the temperature reached 80° C. as shown by a mercury thermometer.

TABLE VIII

*Dog under anæsthesia one and one-half hours before observations were started; abdomen not shaved; room temperature—25.2° C.; electric pad across upper abdomen; chiefly on right side.*

| | | Control ° C. | Thirty minutes ° C. | One hour ° C. | Three hours ° C. | Three and one-half hours ° C. | Four hours ° C. |
|---|---|---|---|---|---|---|---|
| Surf. | Rt. | 34.9 | 42.4 | 44.3 | 44.3 | 44.4 | 44.4 |
| | Lt. | 35.3 | 41.0 | 40.4 | 40.5 | 40.0 | 41.2 |
| Sup. Tiss. | Rt. | 35.4 | 41.0 | 41.1 | 41.8 | 41.7 | 41.8 |
| | Lt. | | | | | | |
| Deep Tiss. | Rt. | 36.0 | 39.5 | 40.2 | 40.8 | 40.9 | 41.1 |
| | Lt. | | | | | | |
| P. C. | R. U. | 36.0 | 37.5 | 37.4 | 38.8 | 39.1 | 39.6 |
| | R. L. | | | | 38.8 | 39.1 | 39.6 |
| | L. U. | 36.1 | 37.4 | 37.4 | 38.8 | 39.1 | 39.6 |
| | L. L. | | | | 38.8 | 39.0 | 39.5 |
| Rectal | | 36.7 | 36.7 | | 38.5 | | 39.1 |

P. C. = peritoneal cavity.
R. U. = right upper.
R. L. = right lower.
L. U. = left upper.
L. L. = left lower

Table IX and Chart VII give the results of an experiment similar to the one just described, but omitting the anæsthesia. It will be noted that in this instance there was little change in rectal temperature and no marked effect on the intraperitoneal temperature.

TABLE IX

*Dog on table thirty minutes; no anæsthesia; room temperature—25° C.; rectal temperature 38.65° C. before placing electric pad across right upper abdomen.*

| | | Control °C. | Ten minutes °C. | One hour °C. | One and one-half hours °C. | Two hours °C. | Three hours °C. | Four hours °C. |
|---|---|---|---|---|---|---|---|---|
| Surf. | Rt. | 34.0 | 42.4 | 42.4 | 42.5 | 42.0 | 41.8 | 42.9 |
| | Lt. | 34.7 | 36.7 | 36.0 | 35.8 | 35.4 | 35.4 | 35.3 |
| Sup. Tiss. | Rt. | 36.3 | 40.5 | 40.5 | 40.5 | 40.0 | 41.2 | 40.0 |
| | Lt. | 36.3 | 37.6 | 37.0 | 37.1 | 37.1 | 36.8 | 37.1 |
| Deep Tiss. | Rt. | 37.3 | 39.7 | 39.3 | 40.1 | 39.3 | 40.6 | 39.3 |
| | Lt. | 36.9 | 37.3 | 37.1 | 37.8 | 37.8 | 37.6 | 37.6 |
| P. C. | R. U. | 37.9 | 38.4 | 38.4 | 38.5 | 38.5 | 38.6 | 38.5 |
| | R. L. | 37.8 | 37.7 | 37.8 | 38.0 | 37.7 | 37.8 | 37.8 |
| | L. U. | 37.9 | 37.8 | 38.2 | 38.5 | 38.0 | 38.0 | 38.1 |
| | L. L. | 38.0 | 37.8 | 37.9 | 38.0 | 37.8 | 37.8 | 37.8 |
| Rectal | | 38.35 | 38.2 | 38.35 | 38.1 | 38.2 | 38.3 | 38.35 |

P. C. = peritoneal cavity.
R. U. = right upper.
R. L. = right lower.
L. U. = left upper.
L. L. = left lower.

In general, when intraperitoneal temperature readings were taken at different locations, no marked difference was observed irrespective of where the thermal applicator was applied. One may assume that, in the dog at least, the temperature in the abdominal cavity normally is about the same throughout. This seems logical if the portal circulation can be considered as the temperature regulator of the abdominal cavity.

Profound narcosis was observed to lower the rectal and intraperitoneal temperatures to a considerable extent in one experiment. In this instance a dog weighing ten kilograms was given 500 milligrams sodium amytal intraperitoneally. This seemed to excite the animal and an hour later a second dose of 250 milligrams of sodium amytal was given. The dog was still restless and noisy, so 65 milligrams of morphine was injected subcutaneously. In a few minutes the animal seemed completely prostrated and the respirations dropped to six per minute. The rectal temperature dropped from 38.9° to 34.5° C. and the intraperitoneal temperature from 38.4° to 33.7° C. The dog later recovered.

In attempting to apply these results clinically, it should be kept in mind that the human abdomen wall is thicker than the dog's and that the fat layer is a poor thermal conductor. Zondek [4] observed a marked difference in the temperature change produced by an ice bag in an obese person as compared to one with a thin, fatty layer. At the same depth in the tissues, the drop in temperature in the fat subject was 1.5° C., and in the thin one 4.5° C.

## SUMMARY AND CONCLUSION

1. Observations on the effects of hot and cold abdominal applications on the dog's intraperitoneal temperature are presented:

(*a*) Cold applications had little effect on the intraperitoneal temperature, the greatest fall being 2.5° C. which was observed in one instance.

(*b*) Hot applications in the form of a hot-water bottle over a towel, as usually used clinically, did not produce any appreciable changes.

(*c*) An electric pad did not influence the intraperitoneal temperature of the normal animal to any great extent, but in an animal under anæsthesia, with a low rectal temperature, it caused a rise of 3.5° C. intraperitoneally. Coincidentally, the rectal temperature rose 2.4° C.

These observations indicate that the beneficial effects of hot and cold abdominal applications are due to other causes than the effect on intraperitoneal temperature.

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DISCUSSION.—DR. BARTGIS MCGLONE said that the first investigators, Becquerel and Breschet, recognized the necessity of minimizing the systematic error due to the thermal conductivity and capacity of the metals used in the thermocouples. Accordingly, the thermojunction was well imbedded in the tissues. Claude Bernard took similar precautions. Bazett and McGlone have shown that, at a depth of ten millimetres, this error is within the limits of the sensitivity of the portable type of apparatus, if the gauge of the needle thermocouple is of the order of 0.4 millimetres or less. At lesser depths the error must be evaluated and a proper correction made. Doctor Brill has described his technic by which the errors cited are reduced to a minimum. Thus the temperature values which he has obtained are significant. The discrepancy between the results of the experiments reported tonight, and those of the Toronto school, are explicable, since it is possible that the trocar used in the latter work may have been of so great a mass as to effect easily and rapidly thermal changes, a contingency against which Doctor Brill has exercised adequate precautions. In this report there are two outstanding features: The adequacy of the methods which Doctor Brill has employed, and the results which he has obtained.

# BILE PERITONITIS AND BILE ASCITES*

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As early as 1772 James MacLurg[1] found the subject of the bile sufficiently interesting to write a monograph on "Experiments on the Human Bile and Reflections on the Biliary Secretion". Herein he states that: "The experiments suggest opinions, which, by their novelty, captivate the mind and hurry it into theory. In spite of ourselves we are carried into the sea which has so often proved fatal to observers and whose rocks, though frequently pointed out, are so difficult to be avoided. We shall give the reflections as they naturally rise from the subject we have been examining, without searching after any other order."

Although MacLurg's work is now forgotten and is rarely referred to in the older literature, it seems likely that it was the incentive for much of the work which has come after it. Many of the theories which have received experimental confirmation in the last decade are discussed by him with a clarity that is indeed refreshing. Among other views he concludes that in the "coloring and bitter part of the bile has appeared to be the production of the animal septic process".

Bile peritonitis resulting from injury, the slipping of a ligature, or from "extravasation" while not very common, is not exceedingly rare. However, until recently the Continental literature discussed the subject much more frequently than did the English literature.

When one attempts to review the subject of bilious ascites, he is confronted with a mass of conflicting evidence. In some instances, so-called "extravasations" of bile are recorded as evidences of massive bile leakage without toxic symptoms. In others, major ascitic accumulations in the peritoneal cavity resulting from portal obstruction and which are bile-stained from an existing jaundice are reported as evidences of bilious peritonitis, although the history and findings do not substantiate the diagnosis. In fact, in nearly every instance wherever fluid resembling bile has been removed from the peritoneal cavity, the material has been called bile and, from time to time, such evidence has been presented in an effort to demonstrate that bile is non-toxic. Buchanan[2] has stated that the reaction of the peritoneum to bile depends on whether the bile is infected or not.

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* Read before the Philadelphia Academy of Surgery, March 4, 1929.

Although for some years considerable thought has been directed to the toxic factor in bile, no one has so far as we know attempted to ascertain whether the bile-stained fluid found in the peritoneal cavity in association with obstruction of the common duct is similar in its action to bile. Neff,[3] in a very excellent review of the surgery of the biliary tract, devotes considerable space to "bilious ascites" and apparently draws no distinction between true bilious ascites and actual bile leakage.

The classic symptoms of bile peritonitis are to a degree variable, depending on the extent of the bile leakage, but in the main they resemble an acute or subacute peritonitis. The patient, as a rule, has fever and an increase in the polymorphonuclear leucocytes. There is early marked abdominal tenderness and rigidity associated with varying degrees of distention as the disease progresses. Vomiting occurs early and is persistent. The urine at first shows evidences of an irritative nephritis and later anuria may supervene. Bradycardia is observed early and hypotension with a slow irregular respiration.

*The Toxic Factor in Bile.*—This subject has attracted the attention of investigators for many years. As previously quoted, MacLurg believed that the pigment and salts were probably both responsible. Later it was shown that the intravenous administration of bile from the gall-bladder of the ox caused death. It was then suggested that impurities in the bile gave rise to capillary thrombi after intravenous injection and Bouisson reported that filtered bile did not cause such lesions and death did not result. Henle,[4] no doubt influenced by Bouisson's work, stated that the widespread view of the toxicity of bile was unwarranted.

The discovery of the bile acids by Strecker[5] and the extensive study of the toxicity of the bile salts by von Dusch[6] dispelled the existing conception that impurities in the bile were the cause of its toxicity. Meltzer and Salant,[7] in 1906, and Simon Flexner,[8] in the same year, again demonstrated the toxic action of the bile salts. Flexner showed that they were the cause of the acute pancreatitis which follows the retrojection of bile into the pancreatic ducts.

Other investigators report results at variance with these opinions. Danielewsky[9] and Flint[10] attribute the toxic moiety to cholesterol. Fasciani,[11] however, was unable to confirm the results of these investigators. Rohrig,[12] Traube,[13] de Bruin,[14] and Sellards[15] concluded that the bile acids are responsible for the effects observed after bile injection. King and Stewart[16] and Landois[17] were of the opinion that the bile salts were either feeble poisons, or were non-toxic. King and Stewart,[16] and King, Biglow, and Pearce[18] came to the conclusion that the bile pigments are the toxic agents of bile or at least the major toxic constituent.

The conflicting evidence is no doubt due to variations in technic, the administration of impure constituents, and failure to properly control the experiments. We have had no experience with the free bile acids, but, as far as we know, these are not found in the bile. That the pigment is the toxic factor seems highly unlikely from accumulated clinical and experimental evi-

dence. In the hemolytic anæmias we have observed considerable pigment retention without the symptoms of bile intoxication. Horrall and Carlson [19] have confirmed previous work that the toxic factor of the bile is the bile salts. They also have found no evidence for the assumption that the bile pigment is toxic and they state that "pure bile acids are non-toxic due to their insolubility". They state, and we have confirmed their observations, that when bile was injected in amounts sufficient to cause death in twenty-four hours, the presence of bacteria did not modify its toxicity. The toxic action was not modified by boiling or freezing. The dialysate of whole bile they found to be toxic while the non-dialyzable portion was non-toxic.

We were interested in those patients who have bile-stained fluid in the peritoneal cavity in association with an obstruction of the common duct. These patients differ markedly from patients who have had extensive bile leakage in that they show no signs of a diffuse or diffusing peritonitis. The fluid resembles bile, but the peritoneum does not react to it as it does to bile. In these patients it would seem that either the toxic factor of the bile is absent entirely, or present in only small amounts, or that some unknown factor prevents the toxic fraction from exhibiting its effect.

As a basis for the present work we estimated the bile salts in whole gall-bladder bile, gall-bladder and common-duct fistula bile and bilious ascites. In this work we have used the method of Aldrich and Bledsoe [20] for estimating bile salts, reading against a standard of sodium taurocholate.

*Estimation of Bile Salts in Bile.*—In these experiments we have utilized bile from several sources. Each specimen was sterilized in an autoclave. The human specimens were obtained from patients subsequent to the production of external biliary fistulæ. The first two specimens of dogs' gall-bladder bile were removed some time after death, which may account for their unusually high content of bile salts. The variation of bile salt content in the human specimens is within the limits found by different observers.

TABLE I

| No. | Type of Bile | Sodium taurocholate Grams/100 c.c. | Remarks |
|---|---|---|---|
| 1 | Gall-bladder—Dog No. 1 | 17.6 | Post-mortem |
| 2 | Gall-bladder—Dog No. 2 | 17.4 | Post-mortem |
| 3 | Gall-bladder—Dog No. 3 | 11.0 | |
| 4 | Gall-bladder—Fistula, human No. 1 | 0.8 | |
| 5 | Gall-bladder—Fistula, human No. 2 | 0.5 | |
| 6 | Common duct—Fistula, human No. 3 | 1.10 | |
| 7 | Common duct—Fistula, human No. 4 | 1.12 | |

*Bilious Ascitic Fluid.*—Table II gives the estimation of the bile salts of the ascitic fluids and also the bile pigment content in the blood and ascitic fluid. The pigment was estimated by the van den Bergh method. The striking point in the table is the low bile salt content of the ascitic fluid in comparison with that found in actual bile.

TABLE II

| Patient No. | Blood | | Fluid | | |
|---|---|---|---|---|---|
| | van den Bergh | | van den Bergh | | Sodium taurocholate (Grams/100 c.c.) |
| | Direct | Indirect (Mg./litre) | Direct | Indirect (Mg./litre) | |
| 1 | Immediate | 33.25 | Delayed | 18.5 | 0.170 |
| 2 | Delayed | 6.5 | Delayed | 3.0 | Negligible |
| 3 | Immediate | 44.0 | Delayed | 7.5 | 0.0065 |
| 4 | Immediate | 10.5 | Delayed | 4.0 | 0.007 |

The bilious ascitic fluids were obtained from the dog (Fluid No. 1) and from patients (Fluid No. 2, 3, 4). The delayed van den Bergh in the blood in a patient who subsequently showed ductal obstruction is difficult to explain. The report was given to us by the hospital laboratory which sent us the specimen. It may be possible that the obstruction had been released and that the delayed reaction with a low pigment content in the blood was a result of this. The uniformly delayed direct reaction in the ascitic fluid may be explained by the fact that it stood some time before study. Andrewes [21] has

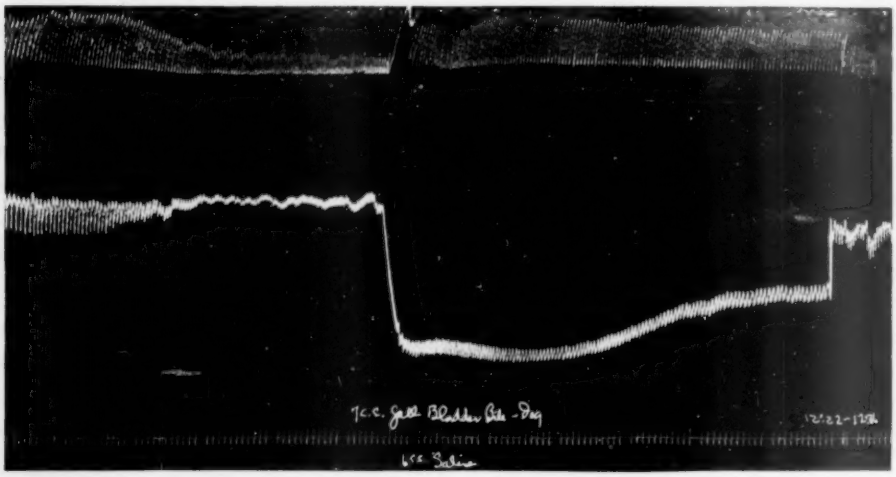

Fig. 1.

shown that a direct immediate reaction becomes a delayed reaction under these circumstances. It would have been interesting to have had the estimation of blood bile salts in these cases and to have compared these with the bile salts in the ascitic fluid. Dragstedt and Spurrier [22] have recently suggested that in obstructive jaundice the formation of bile salts is retarded after complete hepatic secretory suppression occurs. Greene, Aldrich, and Rowntree [23] found that the blood bile salts increased after ductal obstruction for a period of about two weeks when they tended to decrease and return to the normal level. Schalscha and Lande [24] have recently demonstrated a parallelism between the hyper-

bilirubinema and the blood bile salts in mild degrees of hepatic damage. In severe parenchymal damage they found a decrease or a complete disappearance of the blood bile salts.

*Effect of Bile Salts, Bile, and Bilious Ascitic Fluid on Blood Pressure.*—We have found considerable variation in the effect of bile salts in the same concentration and injections of the same bile specimen on the blood pressure of different dogs. In some instances the pressure came back to normal, while in others it remained low or continued to drop, leading eventually to death of the animal. We present (Figs. 1 and 2) the effect on the blood pressure of the same animal of two specimens of bile (dog gall-bladder bile No. 3 and human fistula bile No. 1) as compared with bilious ascitic fluid. The concentration of bile salts in human fistula bile No. 1 was 0.8 per cent., while in the

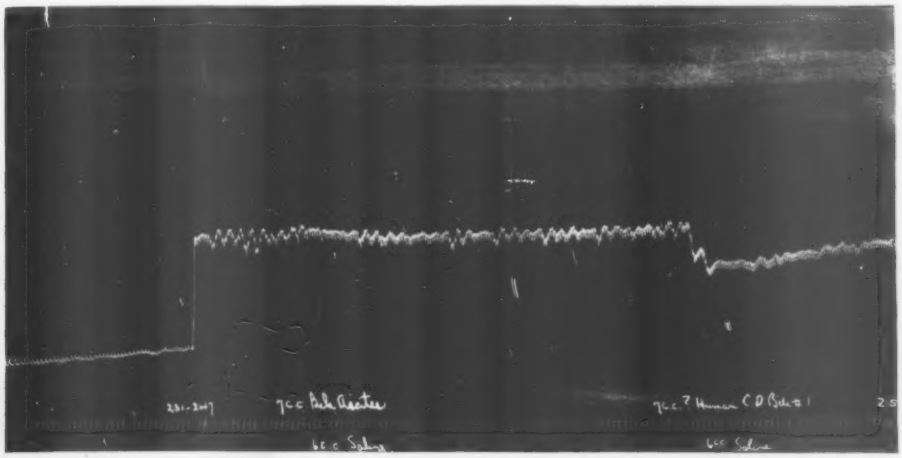

Fig. 2.

dog gall-bladder bile No. 3, the concentration was 11 per cent. In the ascitic fluid the concentration was 0.007 per cent. The fall in pressure varied depending on the bile salt content. There were not sufficient bile salts present in the ascitic fluid injected to alter the blood pressure.

*Effect of Intraperitoneal Injection of Bile Salts on Mice.*—We injected intraperitoneally into mice varying amounts of pure sodium taurocholate. The salt was dissolved in 1 or 1.2 cubic centimetres of distilled water. Control injections of distilled water alone had no effect. (Table III.)

Horrall and Carlson [19] believed that cholesterol acted as a protective agent against the action of bile salts on the blood pressure. They had not studied the effect on mice of intraperitoneally injected bile salt solutions, saturated with cholesterol. We have studied this aspect of the problem and have found no evidence that cholesterol acts as a protective agent against the action of bile salts when used in this manner. (Table IV.) Horrall [25] recently states that apparently lecithin and cholesterol modify the toxic effects of bile salts only slightly.

When whole bile containing calculated amounts of bile salts, similar to those used in the previous injections, was used we found a slightly diminished

TABLE III

*Effect of the Intraperitoneal Injection of Bile Salts on Mice*

| Sodium taurocholate Grams | Death Minutes |
|---|---|
| 0.009 | Lived |
| 0.009 | Lived |
| 0.010 | 95 |
| 0.010 | 300 |
| 0.010 | 420 + |
| 0.020 | 70 |
| 0.020 | 100 |
| 0.020 | 114 |
| 0.030 | 20 |
| 0.030 | 25 |
| 0.030 | 30 |
| 0.030 | 40 |
| 0.040 | 2–3 |
| 0.040 | 14 |
| 0.040 | 18 |
| 0.040 | 21 |
| 0.040 | 26 |
| 0.040 | 30 |
| 0.040 | 49 |

TABLE IV

*Effect of the Intraperitoneal Injection of Bile Salts with Cholesterol on Mice*

| Sodium taurocholate Saturated with cholesterol Grams | Death Minutes |
|---|---|
| .037 | 40 |
| .040 | 7 |
| .040 | 20 |
| .040 | 24 |
| .040 | 28 |
| .040 | 46 |

toxicity. Flexner [8] believed the diminished toxicity of the bile as against pure bile salts was due to the presence of protective colloids. The effect of the intraperitoneal injection of bile is shown in Table V.

TABLE V

*Effect of Bile Injected Intraperitoneally on Mice*

| Calculated Sodium taurocholate Grams | Death Minutes |
|---|---|
| 0.011 | lived |
| 0.022 | lived |
| 0.031 | 126 |
| 0.031 | 240 + |
| 0.033 | 64 |
| 0.037 | 360 + |
| 0.037 | 480 + |
| 0.040 | 71 |
| 0.040 | 120 + |
| 0.040 | 180 |
| 0.044 | 540 + |
| 0.055 | 32 |

The ascitic fluids were used in a similar manner. It was necessary in two instances to concentrate large amounts of the fluids in order to obtain the amount of calculated bile salts which we believed might have any effect on the mouse. Table VI gives the results obtained from the injection of fluids Nos. 1, 3, and 4. It will be seen that the toxic factor, assuming that this factor is the bile salts, was present, but in the concentrations found it is too dilute to cause toxic symptoms in the human.

TABLE VI

| | Sodium taurocholate calculated Grams | Death Minutes |
|---|---|---|
| Fluid No. 1 | .034 | 14 |
| No. 3 | .0092 | 7 |
| No. 4 | .0175 | 96 |

*Bile Peritonitis and Bilious Ascitic Fluid.*—Horrall and Carlson [19] have found and we have confirmed their observation that five cubic centimetres per kilo of body weight of sterile whole gall-bladder bile of the dog injected intraperitoneally will cause the death of the animal within twenty-four hours. The injection of less than three cubic centimetres did not produce any toxic symptoms.

In the abdominal fluid No. 1, obtained from dog No. 411, we obtained 150 cubic centimetres of the ascitic fluid. A small amount of the fluid may not have been removed, but this amount could not have been more than half again the amount removed. The animal weighed eleven kilos and, based upon this and the fluid removed, it is interesting to note the following:

| | |
|---|---|
| Weight of dog No. 411 | = 11 kilos |
| Amount of fluid removed | = 150 c.c. |
| Concentration of bile salts in Ascitic fluid | = .0017 gm. per c.c. |
| Total bile salts in fluid | = 0.255 grams |
| Amount of gall-bladder bile necessary to kill 11-kilo dog | = 55 c.c. |
| Concentration of bile salts in gall-bladder bile | = 0.11 gm. per c.c. |
| Total bile salts necessary to cause death | = 6.05 grams |

Thus the ascitic fluid contains only 4.2 per cent. of the concentration of bile salts necessary to cause the death of the animal.

*Discussion.*—There has been considerable discussion as to whether bile as such can ever gain access into the peritoneal cavity without a perforation of the biliary tract. The opinions are conflicting. Clairmont and von Heberer [26] have apparently published the first experimental work on this subject. These authors recorded a case in which they removed between seven and eight litres of fluid resembling bile from the abdominal cavity of a man who had a large stone in the common duct. No perforation of the biliary passages could be found. Subsequently, as the result of experiments on four dogs, in which they ligated the common duct, and all of which died with intraperitoneal bilious effusion, but without visible perforation of the ducts, they concluded

that the bilious fluid was the result of increased permeability of the bile tract. This filtration they supposed was the result of a pathologic state of the ducts.

With these experiments we cannot agree. Although subsequent to ligation of the common bile duct in the dog, we have found bile-stained fluid in the peritoneal cavity, we have never encountered bile peritonitis except when a technical error occurred at the time of, or a ligature slipped subsequent to, operation. As the result of a severe inflammation of the extrahepatic bile ducts such an increase in permeability might be conceivable leading to a transudation of bile, but in simple obstruction unassociated with acute inflammation, it seems highly unlikely.

It would seem plausible to liken the common duct and gall-bladder to the ureter and kidney pelvis. The hydronephrosis of uretral obstruction is in many ways analogous to the hydrohepatosis of common-duct obstruction. In the former, after obstruction, one does not observe urinary extravasation into the retroperitoneal tissues even though, at times, the ureter may be seriously damaged during the passage of a stone. Schievelbein [27] agreed with the filtration theory and stated that the channels of Luschka's glands offered a site for the leakage.

Blad [28] believed that bile peritonitis could occur without perforation of the biliary passages and explained the transudation of bile by a ferment action of the pancreatic juice on the gall-bladder wall. Animals developed bile peritonitis after the injection of pancreatic juice into the common-bile duct and the subsequent ligation of it. The gall-bladder wall showed no changes macroscopically, but microscopically a total necrosis with softening of the wall was observed. Ingebrigtsen,[29] in discussing Blad's work, suggested that the bile-colored fluid in the abdomen was the result of a general icterus following ligation of the common duct. It can be assumed that only in a very few of the cases of ductal obstruction does pancreatic juice enter the biliary ductal system by retrojection. The pressure necessary for complete hepatic secretory suppression is greater than that necessary for pancreatic suppression, so that in those instances of ampullary or papillary obstructions bile is more likely to enter the pancreatic ducts than pancreatic juice is likely to enter the common duct or gall-bladder. Furthermore, in the dog, the pancreatic ducts enter the duodenum separately from the common duct, so that in this animal the pancreatic retrojection theory is untenable.

Wolff,[30] Ritter,[31] Burchardt,[32] Meyer-May,[33] and Cope [34] express the opinion that a minute perforation probably offers the nidus for the leakage in those cases in which it is difficult to demonstrate larger perforations. Burchardt [32] concludes that "the occurrence of authentic bile extravasation or bile peritonitis without perforation has not yet been proved". Furthermore, "a more plausible view than the filtration theory is the suggestion that the perforation was not found or already healed". This view is more in accord with our own experimental evidence. Minute perforations of the ducts may close readily after the escape of some bile. The low pressure of bile secretion and the natural tendency for this duct to close after incision, if there exists no

obstruction to bile flow into the intestine, leaves little room for argument that an injury to the common duct, or even the gall-bladder, may heal rapidly and subsequently leave little trace of its existence.

Thus we have been led to assume that in those instances in which bile peritonitis occurs there must have been, at one time or other, an opening having a direct connection with the biliary passages. It is not necessary for the bile to be infected in order to cause bile peritonitis. We can produce bile peritonitis in the dog, with death within twenty-four hours, after the injection of sterile whole gall-bladder bile. In those cases in which one encounters considerable amounts of bile-stained fluid in the peritoneal cavity, resembling bile grossly, but in whom there exists no acute symptoms, so far as the fluid is concerned, and the findings at operation disclose no evidence of peritoneal reaction, such as is seen in true bile peritonitis, we must assume that the toxic factor of the bile is either absent or present in amounts which can produce no symptoms.

Obstruction of the common duct results in portal stasis. There is abundant evidence that in the laboratory animal this leads to an attempt at collateral circulation. If the collateral circulation is not efficient, ascites will result. It is our belief that the ascites which occurs during ductal obstruction is bile-stained as a result of general icterus and the bile salts present come from the blood bile salts rather than from filtration through the extrahepatic ductal walls. The recent investigations of Dragstedt and Spurrier,[22] Greene, Aldrich, and Rowntree [23] and Schalscha and Lande [24] would tend to confirm this hypothesis. Since the blood bile salts decrease early in obstructive jaundice and the biliary ascitic accumulations make their appearance later, we should expect a bile salt content comparable to that found in the blood at the time.

SUMMARY

1. An attempt has been made to differentiate those cases in which bile causes a reactive inflammation of the peritoneum and those in which a large peritoneal accumulation of bile-stained fluid is apparently innocuous.

2. The amount of bile salts found in the bilious ascitic fluid in four instances was insufficient to have produced any toxic symptoms.

3. It is inconceivable that such a low concentration of bile salts could be found if the bile-stained fluid were the result of filtration through the walls of the extrahepatic bile ducts.

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DISCUSSION.—DR. GEORGE P. MULLER said that many years ago he operated upon a young boy who had suffered perforation of the gall-bladder twenty-four hours previously, from a gunshot wound, the bullet having cut a small furrow in the liver as well as nicking the gall-bladder. He suffered from symptoms of peritonitis and when opened, the abdomen was found to contain a good deal of bile-stained fluid. The rent in the gall-bladder was sutured and he made an uninterrupted recovery, being entirely free from trouble with his biliary apparatus at the present time, nineteen years later.

A second patient was operated upon elsewhere in October, 1928, and a cholecystectomy performed. The drain was removed in four days, but the patient returned after discharge complaining of abdominal distention and a paracentesis removed several quarts of bile-stained ascitic fluid. This was repeated in December and the patient again submitted to operation, at which time nothing was found except some bile with a good many adhesions. This patient was referred to the speaker on December 31 with a biliary fistula, but a few days later this stopped discharging and he made an uninterrupted recovery with rapid gain in weight and strength. Evidently at the first operation the stump of the cystic duct leaked and the unchanged bile slowly flooded the peritoneal cavity, giving rise to no symptoms except the peritoneal reaction to exudate. Contrary to the first case, there was no admixture here of blood from

the liver or of other elements from the wounds which might have activated the bile into an irritating substance.

In a third case the patient was suffering from cirrhosis of alcoholic and syphilitic origin, in which ascites and jaundice were the prominent symptoms. Here the bile-stained ascitic fluid was simply the bile-stained serum which exuded from the blood. In a fourth patient operated upon for a leak from the cystic duct, the external drainage failed to work and the bile flooded the abdominal cavity, carrying infection and causing fatal peritonitis.

If one studies the sequence of events in these four cases it is apparent that the action of the bile in the peritoneal cavity depends upon the bacterial contents or its power of chemical irritation. Certainly, bilious ascitis and cirrhosis is an entirely different proposition from a leaking cystic duct stump.

# SAFETY FACTORS IN MESENTERIC LIGATIONS*

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The surgeon is often confronted at the operating table with the problem of the viability of the intestine after damage to its circulation in such clinical cases as laceration of the mesentery, mesenteric thrombosis, and strangulated hernia. In lacerations of the mesentery, which are usually accompanied by severe hæmorrhage, one wishes to do the least possible surgical procedure—that is, ligation of the bleeding points and closing of the wound of the mesentery. Radical procedures such as resection of the bowel increase the danger to the patient's life. Recovery from wounds of the mesentery after mere ligation of the bleeding vessels has been reported by Bost.[1] In three cases occurring on the service of Dr. John H. Jopson, although death eventually resulted from complications, autopsy revealed a normal intestine at the site of the injury.

Ross[2] and Klein[3] have reported cases of mesenteric thrombosis which have recovered without surgical interference other than simple laparotomy. In incarcerated hernia where the intestine is somewhat œdematous and doubt may exist as to the competence of the circulation, the bowel is replaced with the hope that the circulation will be reëstablished or a collateral circulation will form and so maintain the viability of the gut. Experience has taught us that this conservative measure is justified.

Anatomical studies of Dwight,[4] Mall,[5] and Eisberg[6] of the arterial supply to the intestine and, especially, Eisberg's study of the arterial supply to the intestinal coats, have given us a clear understanding of the vascular supply of this structure. Eisberg observed that "the blood supply consists of vasa recta arising from the last series of mesenteric arcades and passing directly to the intestine. These vessels generally alternate, one passing in front of, the other behind, the intestine. The vasa recta in passing between the serosa and the muscularis, give off numerous lateral offshoots which unite with similar branches from adjacent arteries. They pierce the muscle coat in the mesenteric quarters. They branch out in tree-like fashion as they approach the anterior mesenteric border and anastomose freely with the similar branches of the arteries of the opposite side. Numerous branches are given off from vasa recta at right angles to the vertical axis of the gut. These branches in turn divide and inosculate with similar branches above and below, as well as laterally, in the submucosa and mucosa. From the plexuses in the latter situation, arteries also arise from the terminal arcades and directly from the vasa

* Read before the Philadelphia Academy of Surgery, March 4, 1929.

recta before the latter reach the muscularis." He believes that there is a well-defined mesenteric border arterial anastomosis in addition to the vasa recta.

Monks [7] has drawn attention in his exhaustive study of the mesenteric vessels, to the variations of arcade of the mesenteric vessels to the different portions of gut. He has suggested that a segment may be localized from a study of the vascularization. In the duodenum there is an occasional arcade; these arcades increase in number in the jejunum until a plexus formation is found in the terminal ileum.

In the intestine of the dog the blood supply is considerably different. Com-

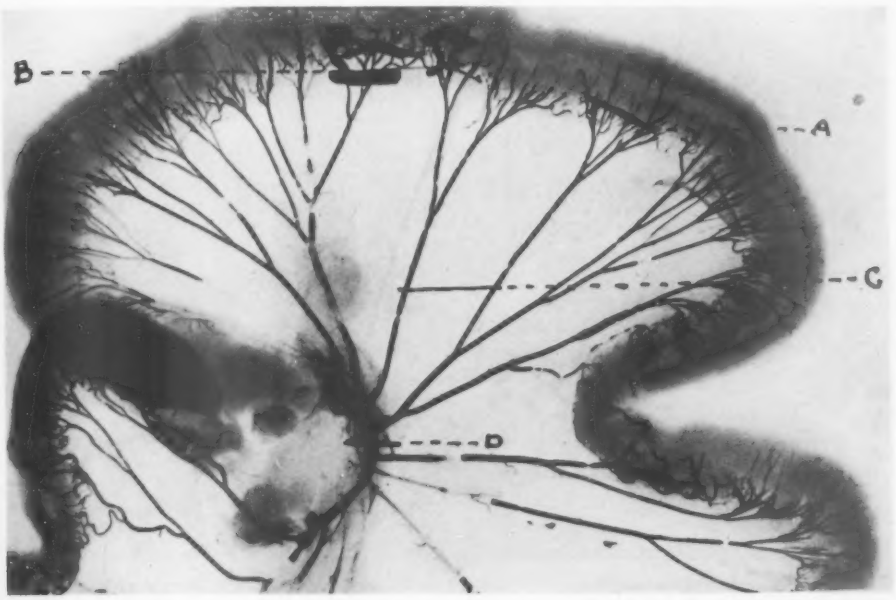


FIG. 1.—Section of intestine of dog with injection of the arteries with oxychloride of bismuth. *A*, *B*, *C*, *D* show the points of severance of the blood vessels. This specimen does not show the arcades, although that was one of the points at which severance was made.

ing off from the mesenteric artery we, as a rule, have numerous branches which at times form one, but rarely more than two, arcades, from which the vasa recta arise. In the majority of instances there is a distinct marginal artery running along the mesenteric attachment to the intestine. This vessel varies in size and at times is so small as to be hardly recognizable.

From an anatomical study one would expect a greater margin of safety in the human because of the extensive vascular plexus formation in the mesentery. (Figs. 1 and 2.) Our experiments were performed upon dogs under amytal anæsthesia (fifty milligrams per kilo), using aseptic precautions. In each instance the vessels, veins and arteries were severed between ligatures, and the opening thus formed was closed. In one case the site of the opening was covered with a portion of omentum. Several conditions were noted constantly. After severing of the vessels, that portion of the intestine supplied by the severed vessels contracted and became purple. Mall [5] made the same

observation with the exception that the intestine became ischæmic. It was also noted by me that the pulsation of all vessels distal to the ligation ceased. Severance of the vessels was performed at five points: (1) Along the mesenteric attachment; (2) through the vasa recta; (3) through the arcade; (4) through the main branches; and (5) through the mesenteric artery. Several of the above series were carried on in the same dog.

*Series A.* Severing of the mesentery along its attachment to the small intestine. Dog No. 1.—Severance of the mesentery for two inches along its attachment; died six days later with gangrene of the intestine.

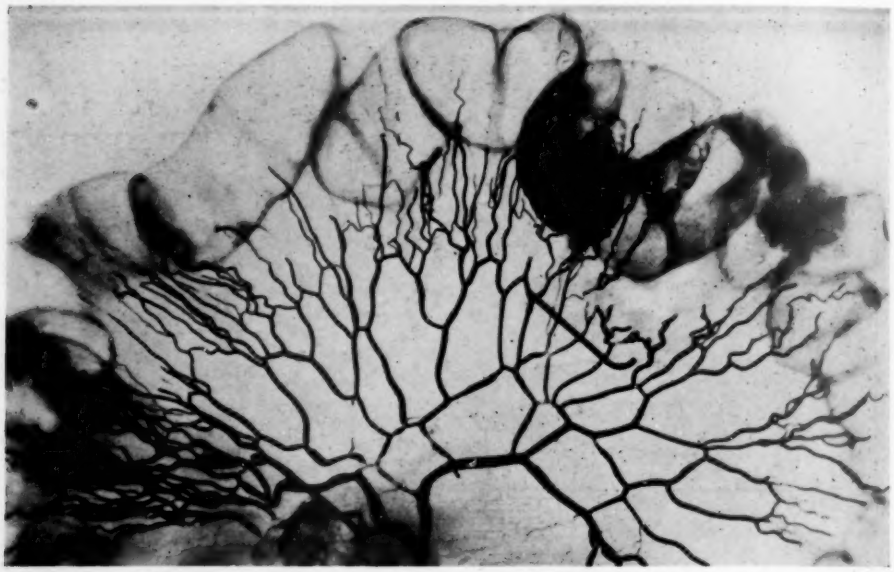

FIG. 2.—Injection of the superior mesenteric artery of the human with oxychloride of bismuth of a portion of small intestine twelve inches from the duodenal jejunal junction. One notes the first, second, and third arcades of this vessel before the vasa recta are given off point of ligation.

Dog No. 2.—Severance of the mesentery for a distance of three inches along its attachment; death twenty-five days later; normal intestine found at autopsy.

*Series B.* Dog No. 3.—Severance distal to the first arcade; portion of omentum placed at site of severance. Autopsy five months and twelve days after operation revealed a normal intestine and numerous adhesions. These vessels were injected with iodized oil and X-rayed. This (Fig. 3) demonstrated that the original vessels distal to the point of ligation contained the iodized oil and that the circulation had been reëstablished through the same vessels. On sectioning the omental graft, we could see the vessels containing iodized oil.

Dog No. 4.—Resection in front of the first arcade for a distance of six inches. Autopsy five months later revealed a normal intestine with numerous adhesions.

*Series C.* Dog No. 5.—Severance of first arcade supplying five inches of intestine. Autopsy four months and four days after operation showed normal intestine with adhesions.

Dog No. 6.—Severance of first arcade supplying five inches of the intestine. Autopsy seven months and ten days later revealed a normal intestine.

*Series D.* Dog. No. 7.—Severance above the root obstructing five inches of blood supply. Autopsy four months later showed normal intestine. Figure 4 shows an X-ray of this intestine after the vessels had been injected with a solution of oxychloride of

bismuth. Here we find that the marginal artery of the segment adjacent to the ligated portion is well developed, and that there are a few small arteries appearing at the site of ligation.

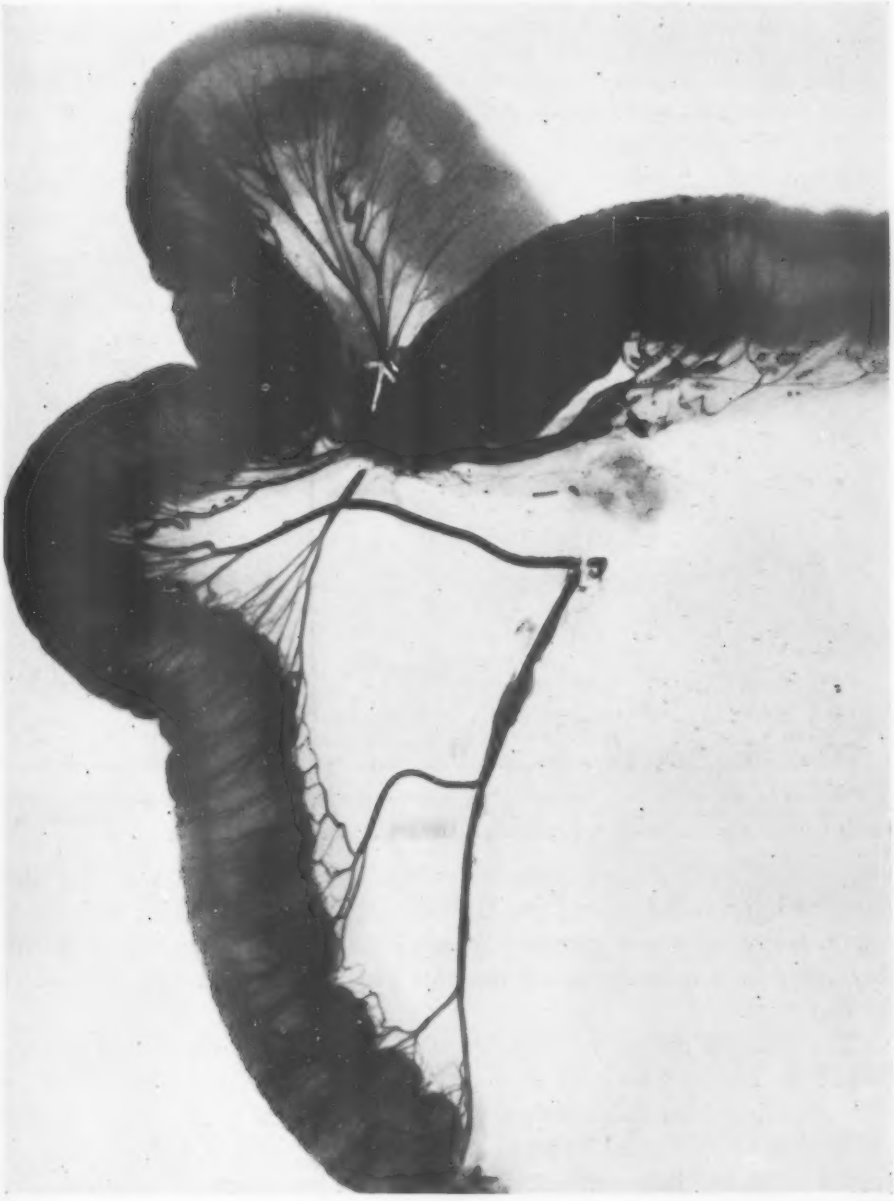

FIG. 3.—Section of intestine found at autopsy of dog five months and twelve days after operation. Vessels were injected with iodized oil. Picture shows the reëstablishment of the circulation through the same vessels.

*Series E.* Dog No. 8.—Severance at the root, four to five inches of intestine involved; died three days later. Autopsy showed gangrene of intestine.

Dog No. 9.—Severance at the root, supplying six inches of intestine; died two days later, showing gangrene of the intestine.

Dog No. 10.—Severance at the root, supplying five inches of intestine; died five days later; gangrene of the intestine.

In the large intestine, there is a distinct marginal artery. It was our desire to resect the mesentery, leaving the marginal artery attached.

*Series F.* Dog No. 11.—Severance of the meso of the large intestine, distance of two inches. Autopsy three months later showed a normal large intestine.

Dog No. 12.—Severance of the meso of large intestine for a distance of five inches, leaving the marginal artery intact. Autopsy five months later showed normal intestine with adhesions.

From the foregoing experiments one can readily see that severance of the blood supply of the intestine between the mesentric attachment and

FIG. 4.—Vessels of the dog's intestine after injection with a solution of oxychloride of bismuth. These vessels were severed at the root. Autopsy four months later. The reëstablishment of the circulation in this specimen was by means of the marginal arteries. Severance indicated by arrow.

the roots offers a great margin of safety, none of the dogs having died from such operative procedure. Involvement of the superior mesenteric artery, *per se,* produced gangrene in each instance. Severance of the mesentery from its attachment to the intestine produced gangrene in but one of the two cases.

The question naturally arises, by what means is the circulation reëstablished? In Figure 3 we have shown by means of the X-ray picture that the circulation has been reëstablished through an omental graft. Thus a communication was afforded between the intact blood supply and the original vessels which had been severed. In Figure 4 we have shown that a collateral circulation was established by the blood vessels adjacent to the severed vessels and that the collateral circulation was established through the marginal artery.

Numerous adhesions were found in all the cases. Some of these adhesions were found at the site of the severance while others were found along the intestinal wall. They were as a rule very filmy in character and grossly did

not show blood vessels of any considerable size. Eisberg [8] believes that the development of adhesions between loops of gut and the omentum are beneficial to the recovery of the affected gut. He also states that there is no evidence of the formation of new blood vessels through these adhesions. I am fully in accord with the first statement. As to the latter one, I feel sure that microscopic sections of the omentum at the site of adhesion would show vas-

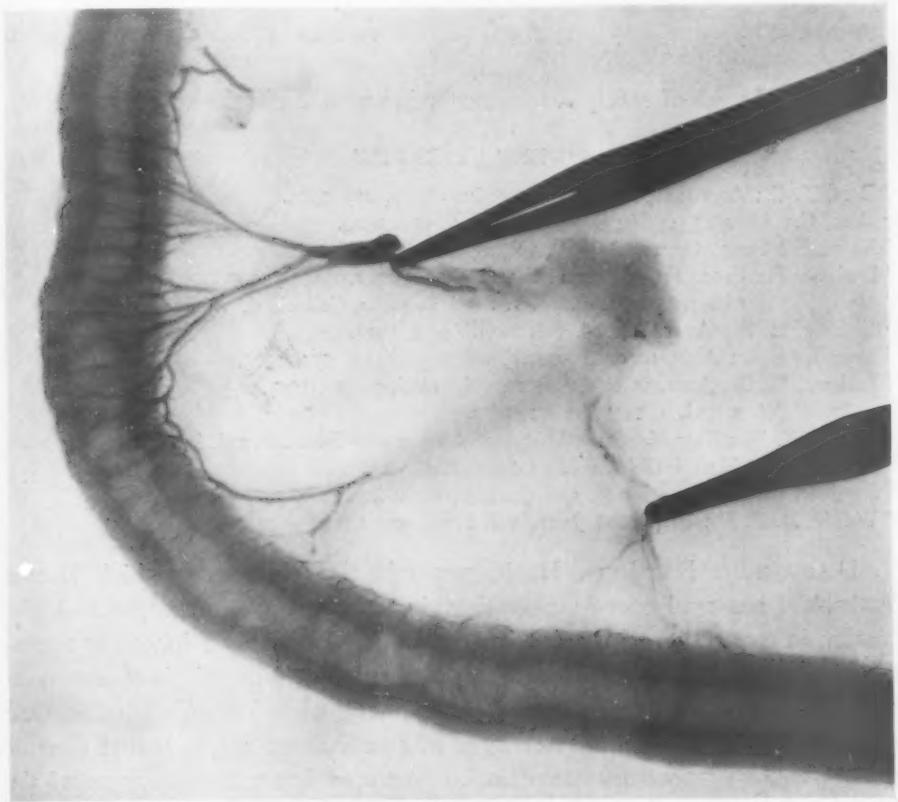

FIG. 5.—Vessels of the dog's intestine injected with iodized oil. This shows marginal artery conveying material to the part supplied by the separate vessels. Severance indicated by arrow.

cularization since Bothe [9] has demonstrated vascularization of even free grafts in a very short time after transplantation. Lanz,[10] Scudder,[11] and Wilkie [12] wrapped omentum around portions of the intestine from which the blood supply had been ligated. Wilkie found intestine intact over three and one-half centimetres long which had had its blood supply ligated. However, it was of no avail over larger areas.

## CONCLUSIONS

1. Interference with the circulation of the small intestine between the mesenteric attachment and the superior mesenteric artery is not usually accompanied by gangrene of the intestine. Interference with the superior mesenteric artery results in gangrene of the bowel. Detachment of the mesentery from

the intestine may not result in gangrene of the bowel. Severance of the mesentery of the large bowel, permitting the marginal artery to be left intact, does not interfere with the viability of the large intestine.

2. The reëstablishment of the circulation in the dog by means of the marginal artery of the segment and by means of formation of new vessels communicating with the vessels severed has been demonstrated. The adhesions in all probability do not play an important part in this. Adhesions of the omentum to the intestine may play a part in the vascularization of small areas of devitalized gut.

3. The degree of safety is far greater in man than in the animal.

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DISCUSSION: DR. JOHN H. JOPSON said that this paper which Doctor Rothschild has read opens up the field for a good deal of thought and discussion in connection with accidental and purposeful lesions following operations on the intestine or injuries to its blood supply. Some of his observations offer an explanation for what we have for a long while known clinically. One of the earliest lessons in the treatment of strangulated hernia is that there is a point in the progress of strangulation where we know that gangrene of the bowel will occur if not resected, and there is another group in which we are reasonably sure the viability has been preserved; and then, a large middle group in which experience many years ago taught us that return of the bowel is usually followed by recovery. The speaker recalled hearing Doctors Wharton and Deaver tell about their own experiences when young operators and the lessons they learned from the teaching of D. Hayes Agnew, who, when watching operations of this type and asked for advice, advised them the bowel be put back; the patients got well. The experience of most surgeons has been that many of the cases which looked doubtful, but in which the bowel was returned, did preserve their viability.

Doctor Rothschild's experiments explain why these cases did not go on to gangrene and how the circulation was reëstablished, by one or the other means which he has demonstrated experimentally. He mentioned the cases of

mesenteric thrombosis reported by Ross and others in which nothing was done but a simple laparotomy.

Doctor Jopson had one such case in which he found extensive mesenteric thrombosis, in which the bowel was returned and nothing further done, and the patient recovered. Doctor Deaver has also had such a case. This problem has been brought home to all of us by operations on the large intestine and especially operations for carcinoma of the rectum in two stages. Doctor Rothschild and the speaker have had unfortunate experiences with ligations of the inferior mesentery artery above the point where it should have been. In fat subjects it is sometimes hard to define just where the line of safety is and they have had some patients go to gangrene. The suggestion of the interposition of a mesenteric graft, or use of it as a covering of the bowel, seems a distinct contribution. The percentage of cases in which it may be used is small, and although we must not apply his conclusions too radically (remembering that the vascularity in dogs is different from that in humans), it is to be hoped at the same time that this contribution will in the future offer a means of overcoming or getting around this question of gangrene in small percentage of doubtful cases.

# THE FATE OF THE FREE OMENTAL GRAFT IN ABDOMINAL SURGERY*

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These experiments were undertaken in an effort to ascertain the fate of the free omental graft used in abdominal surgery. Macroscopic observations and histologic studies were made of the changes which occurred in the grafts from three days to four and one-half months after transplantation. The normal omentum was also studied as a control of the histological changes which occurred following transplantation of small portions of it.

*Technic.*—The grafts were all severed completely from the free border of the greater omentum, bathed in normal salt solution, and sutured to various sites. Care was exercised in avoiding trauma to the grafts during operative procedure. Grafts of various sizes were used, the longest being eight inches, and the smallest a half inch. Both thick and thin grafts were used. All operations were performed upon dogs under aseptic conditions.

The operative procedures in which the transplants were utilized were as follows: (1) Covering the site of the excision of a supposed gastric ulcer. Fluoroscopic and X-ray studies were made before and after operation. (2) Over the closure of an artificially produced perforation of the small intestine; (3) over smooth peritoneum of the small intestine; (4) over areas of small intestine where the peritoneum had been denuded; (5) over the pylorus following a Rammstedt operation; and (6) over the site of a pyloromyomectomy. In this procedure a longitudinal incision about one inch long was made through the pyloric ring in the anterior surface of the duodenum and stomach down to the mucosa. One-half inch of the pyloric muscle was then excised. The resulting serosal defect was not sutured, but was covered over by a free transplant of omentum. Fluoroscopic and X-ray studies were made before and after operation. (7) To cover artificial serosal defects in the spleen and liver accompanied by severe hæmorrhage.

Early in the experiment, black silk was used for sutures, but it was found that too great inflammatory changes occurred around these sutures and plain catgut was substituted. In a few grafts, only a few sutures were used, permitting considerable raw edge to be free. In the remainder, the raw edges of the graft were carefully approximated to the underlying tissue by multiple sutures. The raw edge of the omentum from which the graft had been severed was not inverted in the early experiments. In subsequent operations great care was exercised to cover this raw edge with normal omental tissue. The anæsthesia

* Read before the Philadelphia Academy of Surgery, March 4, 1929.

used was sodium amytal. The dosage was fifty milligrams per kilo of body weight given intraperitoneally.

*Discussion.*—The physiological functions of the omentum are still obscure in certain aspects, although the work of Ranvier,[1] Marchand,[2] Rossle,[3] Seifert,[4] Vogt,[5] Portis,[6] Cunningham,[7] and many other investigators has given us a better understanding of its structure and functions.

Aristotle [8] believed the omentum was a fatty apron designed to protect the viscera from cold. Vesalius [9] thought it was a ligament of support for the transverse colon. Verhagen [10] considered it a device to protect the abdominal viscera from sudden jars and from sudden friction. Hansen [11] was of the opinion that it served to pull the stomach downward when that organ was full and thus facilitated the descent of the diaphragm in respiration.


FIG. 1.—Drawing of a graft over a pyloromyomectomy at two months. (*a*) Graft. (*b*) Long silk suture.

The knowledge derived with the development of abdominal surgery and from experimental studies made on the omentum has established a more scientific comprehension of the functions of this peculiar membrane. This tissue consists of loose, irregularly arranged connective tissue which contains a wide variety of cells. We now believe the functions of the omentum to be: (1) the playing of a very important part in the defense reactions in various pathological conditions within the abdomen; (2) the endowment with movements which are believed to be either "intelligent" or mechanical; (3) the encapsulation of necrotic tissue; (4) increasing the viability of partially devitalized bowel; and (5) usefulness as a graft—free or attached, to cover serosal defects.


FIG. 2.—Drawing of a graft over a pyloromyomectomy at four and one-half months. (*a*) Remaining silk sutures at periphery of graft. (*b*) Grafted area.

The ability of the omentum to increase resistance to peritoneal infection is of the utmost importance in abdominal surgery. Experimental studies have shown this to be due to two characteristics of the omentum; namely, (1) the power of absorption, and (2) mobility. Maximow [12] has so clearly described this reaction that I quote his words. "In cases of inflammatory irritations of the peritoneum, the reactive phenomena develop with the greatest speed and manifest themselves with the greatest intensity in the omentum. If particulate matter of any kind, including bacteria, enters the peritoneal cavity, it is taken up and disposed of by the histiocytes of the

omentum. These elements seem also to take an active part in the elaboration of antibodies. The omentum contains many histiocytes. They are flat, angular or fusiform elements, which may be markedly stretched out and provided with long branched filiform processes. In the so-called milky spots and along the larger blood vessels, the histiocytes constitute the majority of the elements of the tissue. The mobilized histiocytes (macrophages) of the omentum pass in large numbers into the peritoneal exudate. In inflammatory processes, their number in the exudate increases enormously."

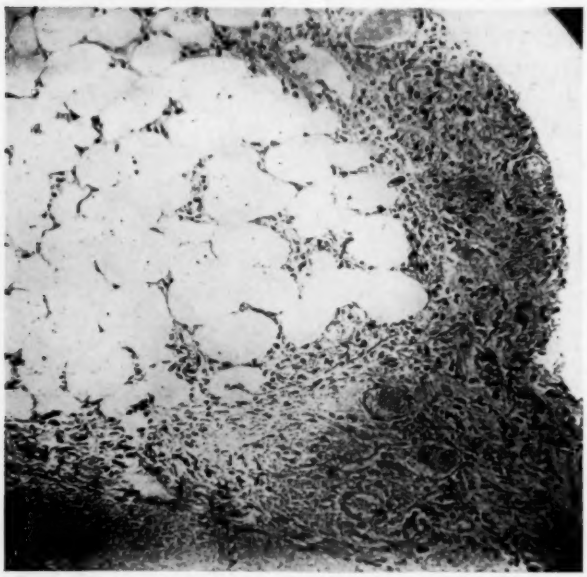

FIG. 3.—Microphotograph of free transplant seventy-two hours after transplantation.

Numerous studies have been conducted to determine the absorptive powers of the omentum and many substances have been used in these studies, *i.e.*, physiological salt solution, india ink, chinese carbon, carmine, defibrinated chicken blood, and bacteria. Wilkie [13] found that cats with and without omenta absorbed salt solution in the proportion of three to two, respectively. When sterilized powdered charcoal was used he found at post-mortem, forty-eight hours after introduction, that all abdominal viscera were irregularly coated with the carbon particles in the cats in which the omentum had previously been removed, whereas in the animals with the omentum intact, the whole of the charcoal was taken up by the omentum and the other abdominal viscera

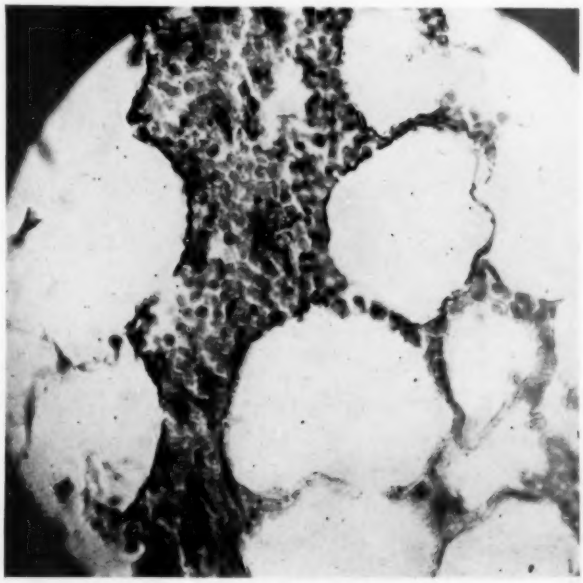

FIG. 4.—Microphotograph of transplant four days after transplantation, showing beginning endotheliazation of newly-formed blood space.

had a normal glistening appearance. He then injected suspensions of staphylococcus aureus into the peritoneal cavity of cats with and without omenta. A few hours after injection he aspirated fluid from the peritoneal cavities and found many cocci in the free fluid and in the leucocytes in those without omenta and few cocci in those with omenta. He later killed a cat with the omentum intact and found this organ densely covered with cocci, many of which were being phagocyted by the mobilized histiocytes (macrophages) of the omentum. The recovery was much more rapid in animals with than without omenta, illustrating the protective action of this structure. Crouse[14] believes the phagocytic protection of the abdominal cavity is mainly due to the ability of the omentum to increase its lymphatic and hæmic activities. Frequently, the omentum is found wrapped around the site of peritoneal inflammation, which may result in localization of the disease. Its function in this particular is most valuable and it has therefore aptly been termed the "policeman of the abdominal cavity".

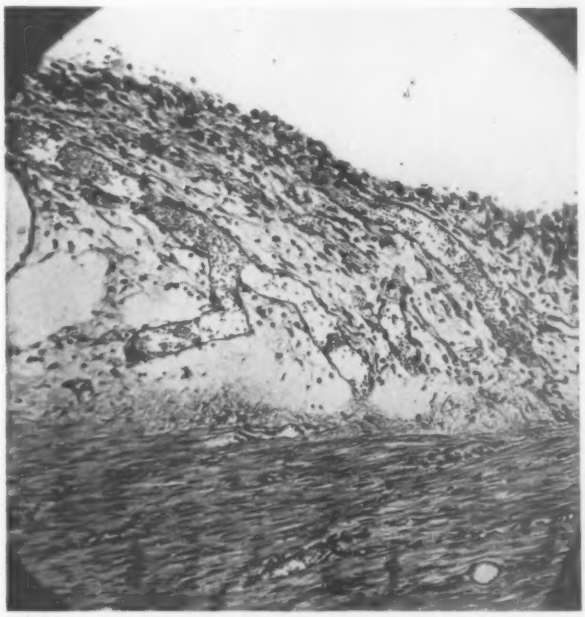

FIG. 5.—Microphotograph of thin graft fourteen days after transplantation.

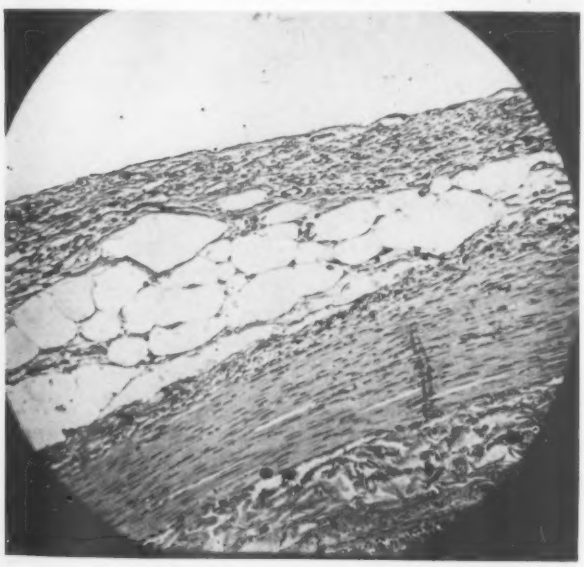

FIG. 6.—Microphotograph of thick transplant fourteen days after transplantation.

Rutherford Morrison,[15] Milian,[16] and others state that the omentum is capable of intelligent movements. This belief is based on the fact that the omentum is so frequently found at the site of the source of an abdominal infection. After moving to the area, the omentum

walls off the infection and is responsible for the localization of many infectious, as well as necrotic, processes, thereby preventing many complications from the development of a generalized peritonitis or toxæmia. The frequency with which this is found has led these investigators to believe the movements are due to an intelligence possessed by the omentum.

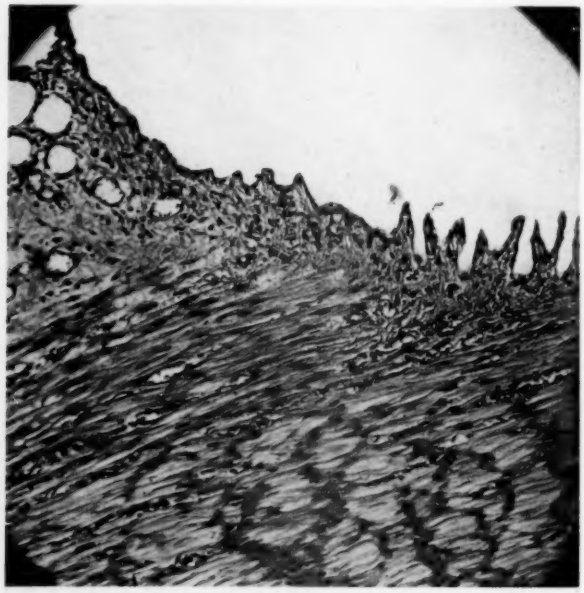

FIG. 7.—Microphotograph of edge of transplant fourteen days after transplantation.

Neusner[17] was the first to regard the movements of the omentum as purely mechanical. The inflamed area is less movable than other parts of the abdominal cavity and, because of the respiratory and peristaltic movements, the free border of the omentum settles at the "quiet spot". There, as the result of inflammatory action, an increased formation of lymph and a roughening of the peritoneal surface has taken place. In a short time, the omentum becomes adherent and encapsulation results. A protective, fibrinous exudate appears which seals off the attachment of the omentum to the inflamed area. At one time, chemiotaxis was thought to play a part in the movements of the omentum to the inflamed area. This has only been a hypothesis, however, and there has been no scientific evidence forthcoming which would lend weight to this view.

FIG. 8.—Microphotograph of thin transplant two months after transplantation.

In this experimental study, the omentum became adherent to the in-

testine twice, producing obstruction. From this it would appear that the omentum is not endowed with "intelligence" which conducts these movements, but, on the other hand, it adds strength to the belief that the motility of the omentum is purely mechanical.

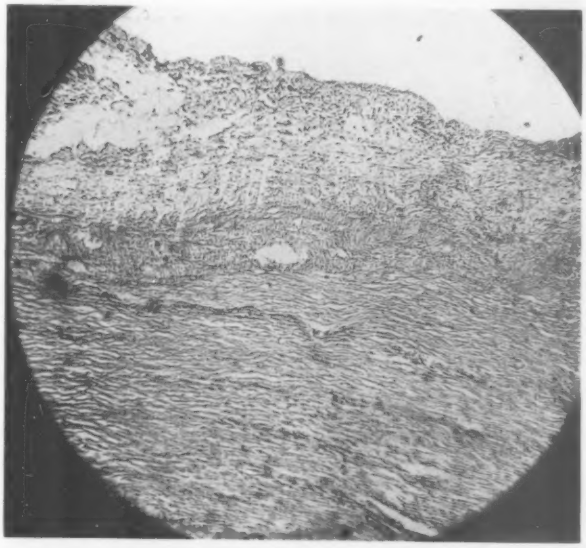

FIG. 9.—Microphotograph of thin transplant four and one-half months after transplantation.

The ability of the omentum to encapsulate necrotic tissue was first demonstrated by De Rienzi and Boeri [18] in 1903. They ligated the pedicle of the spleen, and, to their surprise, the animal lived. Some weeks later at autopsy, they found the spleen to be a small fibrous nodule encapsulated in the omentum. Similar experiments were then performed on dogs in which the omentum had been removed, and all the animals died from toxæmia from absorption of products of decomposition from the spleen. This work has been confirmed by Pirone [19] and Wilkie.[13] These results suggested the wrapping of omentum around a strangulated portion of intestine, the viability of which was doubtful, or when the patient's condition did not warrant resection. Only recently, Bost [20] has described a similar use of the omentum with successful results. Lanz,[21] Scudder,[22] and Wilkie [13] wrapped omentum around portions of the intestine from which the blood supply had been ligated. Wilkie [13] found the intestine intact in an area three and one-half centimetres long which had had its blood supply shut off, but it was of no avail in larger areas. He concluded that wrapping with omentum was of value in partially

FIG. 10.—Microphotograph of thick transplant four and one-half months after transplantation.

devitalized intestine in that it prevented perforation and peritonitis when the area was small.

The omental grafts employed extensively in abdominal surgery to cover serosal defects are of two types: (1) The free transplant; (2) the attached. The attached grafts are used less frequently as the indications are fewer in number and the possibility of internal herniation or adhesions with subsequent obstruction are too great, to say nothing of the traction on the stomach or transverse colon with resulting torsion of these organs. The attached grafts, however, are preferable in the presence of infection. Experimental studies, particularly those of Peet and Finton [23] and Davis,[24] have clearly shown that free transplantation of the omentum is not successful when infection is present. Senn,[25] in 1888, was the first to advocate the use of the free omental graft. He found such portions of the omentum adhered firmly to the surface to which they were applied, became vascularized, and he observed no untoward results from such grafting.

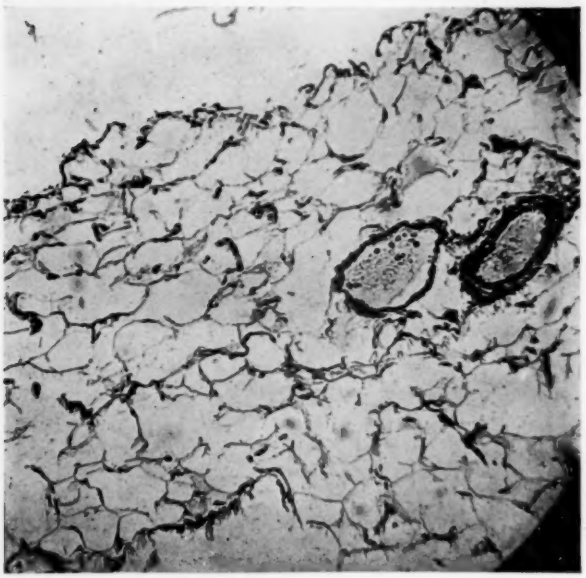

FIG. 11.—Microphotograph of normal omentum with sparse vascularization.

On the contrary, after a careful study, Rubin [26] concluded that detached omentum becomes necrotic and is useless. C. H. Mayo [27] states that free grafting of the omentum is a temporary patch which soon undergoes necrosis and becomes absorbed after serving its purpose. Peet and Finton,[23] in a

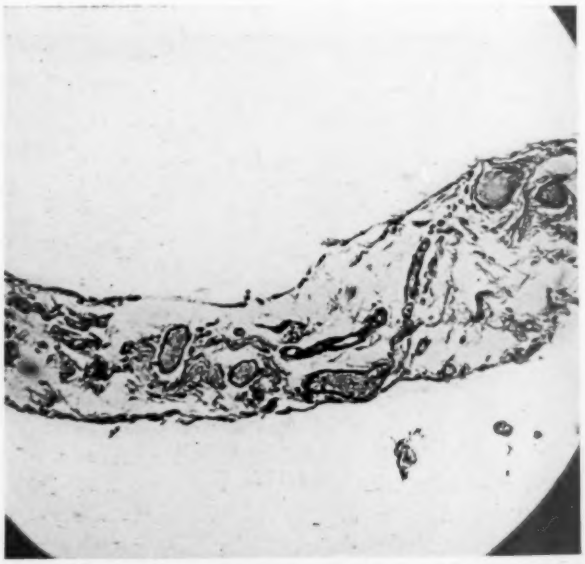

FIG. 12.—Microphotograph of normal omentum with rich vascularization.

histological study of omental grafts, concluded in the absence of infection, the thin graft survives at least six months practically unchanged. Brocq, Ducastaing, and Reilly [28] were the first to establish the fact that the free transplants were not only successful, but, in addition, the surface endothelium of the transplanted omentum persists.

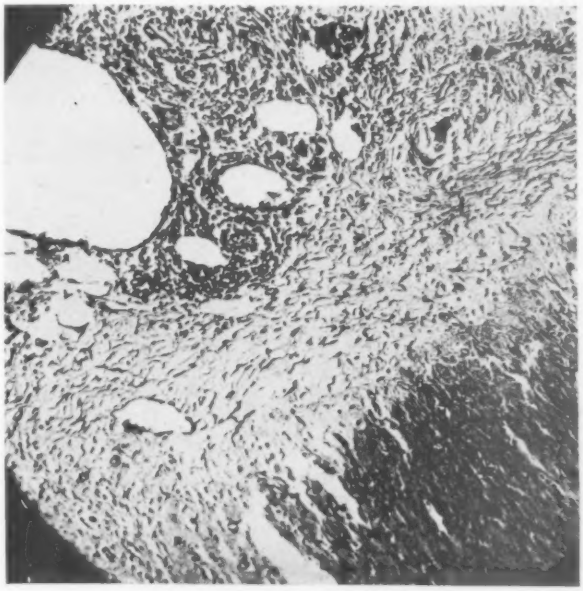

FIG. 13.—Microphotograph of two portions of same graft, illustrating different degrees of cellular changes at three weeks. See Fig. 14.

Springer [29] and Wilkie [13] believe it to be a satisfactory procedure, but contend that this practice has unavoidable disadvantages in that it almost inevitably leads to extensive peritoneal adhesions. Bennett,[30] in 1896, and Braun,[31] in 1897, reported successful results obtained from covering perforated gastric ulcers with omental grafts. Tietze,[32] Enderlen,[33] Reering,[34] and E. J. Senn,[35] used the omentum on intestinal work on dogs and proved its ability to seal, occlude and serve as a vehicle for mucous membrane development over the gastric defect. Later, Hesse [38] recommended its use to strengthen sutures in operations on the stomach, colon, and urinary bladder. Brocq, Ducastaing, and Reilly [28] recommend the utilization of free transplants to peritonealize the denuded area following resection of kinks or adhesions at the ileocolic junction.

FIG. 14.—See Fig. 13.

In addition to these clinical observations and experimental studies, a large number of conditions have been reported in which free omental grafts have been used suc-

cessfully in abdominal surgery; *i.e.*, to cover incomplete peritonealization of the false pelvis in pelvic surgery, the burying of the stump of cystic duct or Fallopian tube, covering the duodenal stump after gastric resection, reënforcement of the peritoneum in threatened perforations.

FIG. 15.—Microphotograph of unsuccessful transplant on smooth peritoneum two months after transplantation.

Loewry,[36] in 1900, was the first to describe the hæmostatic action of the omentum. He used it successfully to control hæmorrhage from the liver and found it became rapidly attached to the liver and soon became difficult to detach. L. Stucky[37] reported a case of profuse hæmorrhage from the liver bed following cholecystectomy. The only method he could find effective to control hæmorrhage was the use of a free omental graft. The patient died three days after operation, and at post-mortem examination the graft was firmly adhered to the liver and there was no free blood in the abdomen.

Hesse[38] made similar observations and demonstrated capillary formation in the transplanted omentum in three to four days. He cited eighty-nine cases of traumatism of the liver that came under his observation in seventeen years. Of seventy-nine cases treated by suture, cauterization, and tamponade, 39.3 per cent. died. The last ten cases in this series he treated with free omental transplantation without a single death.

FIG. 16.—Microphotograph of transplant on smooth peritoneum two weeks after transplantation, demonstrating necrosis.

*Results.*—The earliest macroscopic observations in these experiments were made seventy-two hours

after transplantation. The raw edge at the junction of the graft with the underlying tissue was covered with a plastic exudate. Traction on the graft at this time showed it to be adherent, but it could easily be detached by force. When the graft was lifted bleeding occurred from the under surface. At the end of two weeks the surface of the grafts was smooth and they could only be removed by forceful traction.

No gross changes were noted in the appearance of the grafts from two weeks to two months after transplantation. At two months, however, the grafts appeared as if partial absorption had occurred, though they were still in evidence and were definitely elevated from the surrounding surface as is represented in Figure 1.

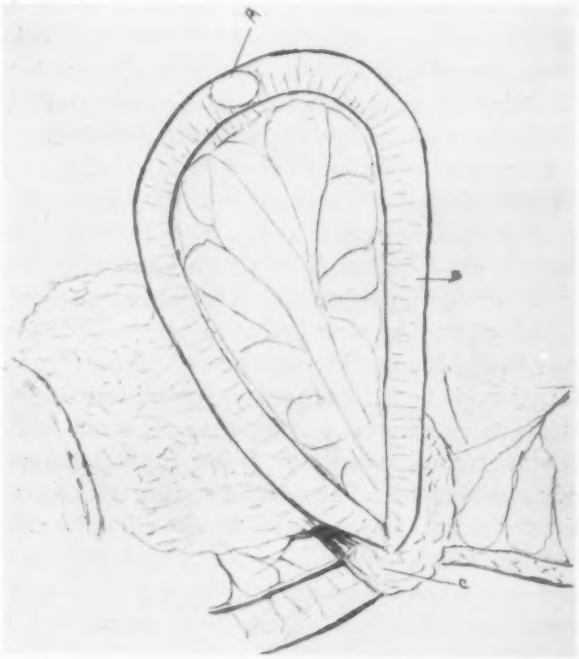


FIG. 17.—Diagram of a raw edge of omentum from which graft was taken, becoming adherent to another portion of itself, producing intestinal obstruction. A.—Free graft. B.—Small intestine. C.—Adherent greater omentum producing intestinal obstruction.

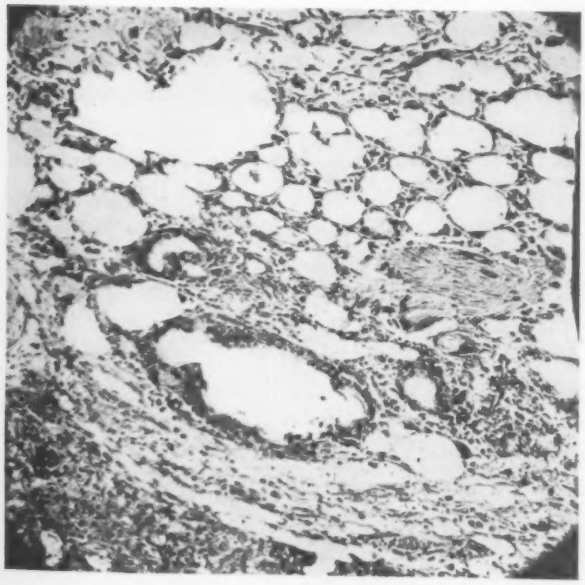

FIG. 18.—Microphotograph of transplant in wound of liver thirteen days after transplantation.

At four and one-half months the thin graft was entirely absorbed and it was not possible to distinguish the outline of the area over which it had been sutured. The fat graft was easily identified at this time and apparently very little if any absorption had occurred. Figure 2 is a drawing from a specimen removed at autopsy four and one-half months after a thin graft had been sutured over the serosal defect of a pyloromyomectomy. The black

silk sutures which were used were the only means of identification of the outline of the graft.

*Histological Findings.*—Chronological histological studies revealed the actual cellular changes which occurred in the transplanted omentum. The earliest section was that of a graft three days old which was entirely adherent to the bowel wall at that time. Many young blood spaces and a few young fibroblasts were scattered throughout the graft. At this early date the endothelial layer of the graft proximal to the bowel wall was beginning to undergo degeneration. The junction of the edge of the graft with the bowel wall was smooth, though endothelium had not grown over it. (Fig. 3.) At the end of four days there was evidence of beginning endothelialization of the newly-formed blood spaces. (Fig. 4.) At fourteen days the graft had the appearance of young fibrolipoid tissue. Scattered throughout were a number of vascular spaces of various sizes and ages, manifested by the presence and absence of endothelial lining. In some areas the fatty content of the fat cells was no longer evident, and there was a marked increase in fibroblastic and angioblastic elements, more pronounced on the proximal surface. The endothelial cells on the under surface of the graft had entirely disappeared. (Fig. 5.) The number of remaining fat cells varied. In one graft only a few fat cells were found at the periphery. In others, they were still quite abundant throughout. (Fig. 6.) The endothelial covering of the graft had joined that of the recipient organ and was continuous with it. (Fig. 7.) At twenty-one days in thin grafts the fat tissue had almost entirely been replaced by dense angioblastic and fibroblastic proliferation. At this time the angioblasts and fibroblasts could be seen infiltrating into the underlying tissue. (Fig. 13.) In the fat grafts these changes occurred in the proximal portion, but very little change was found in the peripheral fat cells.

At two months vascularization was mature and the fibroblastic proliferation was far advanced. The graft appeared as a layer of fibrous tissue which had grown over the surface of the underlying tissue. (Fig. 8.) Numerous fat cells were still visible in the fat transplants.

At four and one-half months there was considerable difference between the microscopical picture of the thick and thin grafts. In the thin grafts no fat cells were visible, the fibroblasts had undergone marked absorption and the vascularization was greatly diminished. The endothelial covering was complete. (Fig. 9.) The thick graft still possessed the fibroblastic and angioblastic tissue unchanged and fat cells were present in abundance. (Fig. 10.)

The only noteworthy finding in the histological study of the normal omentum was the difference in the degree of vascularization. Some sections contained numerous blood vessels, others relatively few. The extremes in vascularization are represented by Figures 11 and 12. This observation was thought to be of significance as indicated by the cellular changes found following transplantation.

Several factors were responsible for variation in the histological findings just described. Cellular changes in the grafts varied in dogs examined at similar periods after transplantation in which the same types of grafts were

used under similar conditions. As the changes were not uniform in dogs, it is reasonable to deduce similar circumstances occur in the human. In fact, different parts of the same graft showed variations in angioblastic and fibroblastic proliferation. (Figs. 13 and 14.) This was thought to be due to the distribution of the blood vessels in the graft employed, though the degree of vascularization of the grafts used was not noted at the time of transplantation. As measured by cellular changes, the thin graft is preferable. These observations lead to the deduction that the ideal graft should be thin and well vascularized.

The grafts transplanted upon the smooth peritoneum united less satisfactorily. The only unsuccessful transplant was in this group. In this instance at post-mortem examination the graft was entirely disappeared and the black silk used for sutures was found in the adjacent mesentery of the intestine. (Fig. 15.) Microscopically, the incomplete union was apparent, fewer cellular changes were noted in their structure and several grafts showed necrotic changes. (Fig. 16.)

The development of post-operative adhesions has been the objection some surgeons have made to the use of omental grafts in abdominal surgery. Early in this study, the adhesions found at post-mortem examination were of three types: (1) In large grafts the raw edges of the omentum on adjacent loops of bowel would become adherent, producing angulation with resulting obstruction and death; (2) the greater omentum would become adherent to the raw edge of the graft (apparently harmless adhesions); (3) the free border of the greater omentum from which the graft had been severed would become adherent to another portion of itself or other abdominal viscera. The technic was modified in an effort to overcome these complications. Smaller grafts were employed and results showed that the raw edge of a graft larger than five centimetres, when transplanted to the small intestine, became adherent to another portion of itself with resulting angulation of the bowel and its sequelæ. Subsequent formation of adhesions to the graft was largely, though not entirely, overcome by careful suturing of the graft to the viscus. This procedure decreased the amount of raw edge exposed and thereby decreased the possible formation of adhesions.

When only a few sutures were used to hold the graft in place, adhesions were invariably found at autopsy. Though this type of adhesion is apparently harmless, care should be taken to minimize its formation. Peet and Finton [23] suggested inversion of the raw edge before suturing the graft. This procedure was not employed as it is more time-consuming and necessitates greater trauma to the graft.

The raw edge on the free border of the omentum was carefully covered in the later experiments. Two fatalities demonstrated the necessity of this procedure. In both instances there were no adhesions to the grafted areas, but the raw edge on the free border of the omentum had wrapped itself around a piece of small intestine and become adherent. Fibrosis with contraction occurred producing obstruction with subsequent death. This is rep-

resented diagrammatically by Figure 17. The cut edge was ligated with black silk and the silk ligature was found at the site of the adhesions, proving that the raw edge from which the graft was removed had become adherent and was responsible for the obstruction. This is by no means a new observation. Davis,[24] in 1917, in a report of an experimental study of omental grafts, suggested that the raw stump of the proximal portion of severed omentum must also be rolled back under normal tissue to avoid adhesions. These two fatalities made a profound impression as to the dangers of not covering the raw edges from which the graft is severed. This may be overcome by rolling back the raw stump under normal omental tissue as suggested by Davis, or by actual inversion between two layers of the omentum. This type of adhesions did not occur after the above precaution was adopted.

The hæmostatic action of the free omental graft was very clearly demonstrated. Stab wounds were made in the liver and spleen and pieces of spleen were actually gouged out. In these experiments the hæmorrhage was profuse and beyond control by pressure. Free grafts were sutured over the injured areas and the bleeding was controlled almost instantaneously. Although there was considerable hæmorrhage beneath the grafts, they were all completely united to the underlying tissue and there was definite angioblastic and fibroblastic proliferation within the grafts. Figure 18 is a microphotograph of a transplant covering a wound in the liver thirteen days after transplantation. The microscopical findings were the same when the transplant covered a defect in the spleen.

X-ray and fluoroscopic examinations were made upon the dogs before and after excision of a supposed gastric ulcer and pyloromyomectomy. The dogs were anæsthetized with sodium amytal for these studies. The anæsthetization diminished peristalsis so markedly that satisfactory deductions could not be made. However, at post-mortem examination there was no visible defect in the stomach or pylorus after these operative procedures. Upon opening the stomach, the mucosa had apparently grown over the site of the excision of an ulcer at three weeks, though it was greatly puckered at this point. Obstruction did not occur following pyloromyomectomy, the pylorus was patulous and there was no evidence of contracture.

## CONCLUSIONS

1. Thin omental grafts are preferable to thick grafts for free transplantation.

2. The ideal graft should be thin and well vascularized.

3. Care should be exercised to cover the raw edge on the free border of the omentum from which the graft is severed.

4. Free transplants should be carefully sutured to the underlying tissue.

5. Free omental grafts unite far more satisfactorily when the peritoneum has been denuded.

6. Union is complete and young blood spaces and fibroblasts are found in transplants seventy-two hours after transplantation.

7. Endothelialization of newly-formed blood spaces begins ninety-six hours after transplantation.

8. The surface endothelium persists and at two weeks is continuous with the endothelial covering of the recipient organ.

9. Angioblastic and fibroblastic proliferation is pronounced the first two months after transplantation. Subsequently, absorption occurs and there is almost complete absorption of the thin graft at four and one-half months.

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Discussion: Dr. John Speese said that the results of these investigations have been particularly interesting and valuable as it has been possible to apply many of these principles in clinical work in which Doctor Bothe has been associated with him. In fact some of the problems worked out experimentally, such as the relative value of the large or small, the thin or the thick transplant, were suggested in the course of operations in certain types of cases in which omental transplants had been used.

During the past few years he had encountered numerous instances of ileocæcal obstruction, cases in which removal of the appendix had not been followed by success insofar as relief of symptoms was concerned. In these cases the terminal ileum is thickened, the opening into the cæcum is not demonstrated easily because of adhesions existing between the ileum and cæcum. If the ileum is released by careful dissection, the ileocæcal opening then becomes apparent. The resulting peritoneal defect has been covered with omental grafts after the manner described in Doctor Bothe's experimental work.

The results obtained in some of these patients has been gratifying, particularly when constipation has been a conspicuous symptom. It has seemed that narrowing of the ileocæcal opening by preventing the liquid content of the small bowel from gaining ready access to the cæcum has been more or less responsible for the development of constipation in certain cases.

In a few cases in which appendectomy, previously performed, had been followed by a continuation of symptoms such as pain and constipation, relief has been secured by the above described measure.

Doctor Bothe and the speaker have reported cases in which they have endeavored to relieve pylorospasm by partial pyloromyomectomy, and in these cases have covered the incision with an omental graft. They have hesi-

tated to do such a radical operation as recommended by Martin and Burden and have secured favorable results with relief of symptoms by partial division and resection of the muscle. In order to prevent adhesions they have covered the defect by an omental graft. The use of omental grafts has proven valuable also in controlling bleeding in the Rammstedt operation for pyloric stenosis in children. The application of a bit of omentum here held in place by a single suture has seemed to be more efficient than an attempt to ligate the small vessels.

Ligation of large areas of omentum may be followed by adhesion of the ligated stump to the intestine. The practice, therefore, of infolding the omental stump is to be endorsed and should be carried out in all such instances. In cases in which the omentum is wrapped around an inflamed appendix, after removal of the portion of the inflamed omentum, it is desirable, if feasible, to shorten the omentum by infolding in order to prevent its adherence to the ileum which has been found to be the cause of intestinal obstruction in several recent cases.

# THE SMALL DEEP GRAFT

## RELATIONSHIP TO THE TRUE REVERDIN GRAFT*

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FROM THE SURGICAL DEPARTMENT OF THE JOHNS HOPKINS UNIVERSITY AND HOSPITAL

The object of this paper is to trace the evolution and use of a type of small graft which contains more of the corium than the superficial graft developed by Reverdin and to inquire into its relationship to the true Reverdin graft. Incidentally, I hope to interest those of you who are unfamiliar with these grafts so that you may at least give them a trial, as I have found them most useful in solving both simple and complicated problems in wound healing. At the risk of repeating statements which I have made, I will again call attention to certain points.

Twenty years ago when making a study of the patients which had been skin grafted at the Johns Hopkins Hospital, I found that among the first five hundred and fifty cases there were notes in two instances on what were called Reverdin grafts. The patients on whom these grafts were tried were negroes and both the lesions were leg ulcers. In one case, the grafts were used after the partial take of a white Ollier-Thiersch graft, and in the other, as a fifth attempt after partial failures of auto and iso-Ollier-Thiersch grafts. In both instances, these small grafts took and permanent healing followed. It occurred to me that these grafts might well be used more frequently as they seemed to be successful in particularly resistant cases where larger grafts had failed. At that time I had never seen a Reverdin graft used either at the Johns Hopkins Hospital or at any other hospital which I had visited, as this type of graft had been almost completely superseded by larger Ollier-Thiersch grafts of the same thickness. So becoming interested, I began to look up literature on the subject and found it voluminous, especially in the early '70's.

The hastening of the healing of granulating wounds by the transplantation of small bits of epidermis was first demonstrated by J. L. Reverdin, a young Swiss intern in the Necker Hospital in Paris, in Guyon's service. His report was made to the Société Impériale de Chirurgie on December 8, 1869, where he showed a patient on whose thumb he had transplanted bits of epidermis. He described the original process as follows: "I raised with the point of a lancet two little flaps of epidermis from the right arm, taking care not to cut the dermis." These bits of epidermis planted on the granulating surface lived and grew and with the addition of others caused partial healing. This paper was discussed on December 15, 1869, but, with the exception of Guyon and Marc See, no one in France seemed to realize the importance of the discovery that bits of epidermis could be transplanted, and would live and proliferate. G. S. Pollock, of St. George's Hospital, London, hearing of Reverdin's

* Read before the Southern Surgical Association, December 12, 1928.

FIG. 1A

FIG. 1B

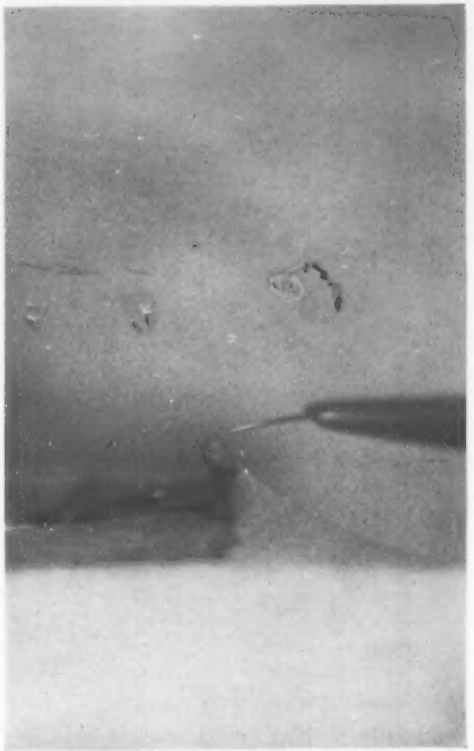

FIG. 1C

FIG. 1.—*Steps in Cutting a Small Deep Graft.* Fig. 1A.—Shows the point of a needle, held in an artery clamp, lifting up a little cone of skin. Note the edge of the knife against the base of the cone with the blade tilted slightly downward. The cone of skin is being raised from the margin of the rectangular-shaped area marked out and stained with brilliant green, and this shows as a dark patch against the surrounding skin. The same patch will be noted in the other photographs of this group. Fig. 1B.—Shows the graft cut halfway through. Note the downward tilt of the blade as it cuts into the skin through the base of the cone. By tilting the blade downward as far as the centre of the graft the full thickness of the corium is usually included at the point. Fig. 1C.—Shows the tilting up of the knife blade in cutting the second half of the graft. thus reversing the process, going from the thick centre to the thin margin. In this photograph the process of cutting the graft is nearly completed.

work, first used his type of graft in May, 1870, with great success and the method was enthusiastically taken up by various surgeons in England, from whence it spread to the United States and other countries.

In Reverdin's original operation, as noted above, he obtained his grafts from the arm, but later he utilized the inner surface of the leg in the following way: He held the skin tense over the flat surface of the tibia and introduced the point of a rather large venesection (double edged) lancet parallel to the bone, and to the depth of 0.5 millimetre. The lancet was then pushed forward so that the point would emerge two or three millimetres farther on, the small piece of epidermis being cut loose by the edges of the lancet. He adds that the little wound is the seat of a fine sanguineous dew.

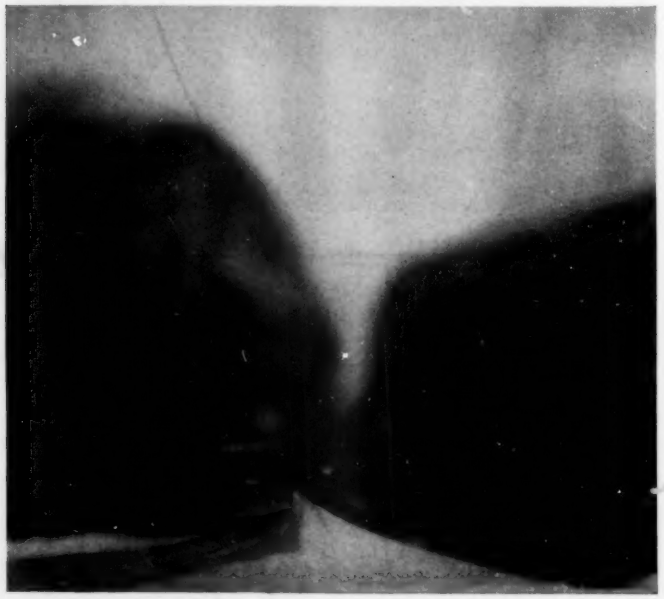

FIG. 2.—*Method of Cutting a Reverdin Graft.* The little cone of skin is raised by the needle just as if a Small Deep Graft were to be cut. Note that the knife blade is held flat at the level through which the tip of the cone is to be cut across. In this way by cutting close to the needle the thinnest possible graft can be removed. Compare the position of the knife and the level to be cut in Figs. 1 and 2, and it will clearly show the difference between a true Reverdin and a small deep graft.

When a small deep graft is cut, [illegible] anæsthesia has been induced by infiltration with novocain containing adrenalin, there is free bleeding from the wound from which each graft is taken, showing that a much greater depth of skin is removed and this clearly indicates the difference in thickness between a true Reverdin graft and a small deep graft.

Grafts obtained by Reverdin's method are usually thought of as pure epidermic grafts, and in his articles, Reverdin always spoke of them as *"greffe epidermique,"* but in his exhaustive paper on the subject published in 1872 he says in part: "The title *'epidermic grafts'* is not perfectly correct, as the transplanted bit is composed of the whole epidermis and a very little of dermis."

In other words, Reverdin described the graft which is named for him as a pure epidermic graft, but later found that it consisted of the epidermis and a very thin layer of the corium. In short, it was the thinnest graft that he could cut. Little is found in the literature on Reverdin grafts after the '80's, until an excellent article by Ehrenfried and Cotton was published in 1909.

Experimenting with the Reverdin type of graft, I also found by microscopic examination that it was impossible to cut a pure epidermic graft, how-

ever thin the graft might seem to be, except possibly on the bottom of the foot where the epidermis is very thick. I noted that grafts which were deeper and contained more of the corium took as well and gave a more stable healing than when the thinner Reverdin grafts were used. In 1914, after five years of experimenting with different thicknesses of small grafts, I reported the results of this study, which was based on a large number of cases grafted with small thick grafts which will be described below, and I called these grafts "small deep grafts".* The grafts are somewhat larger

FIG. 3.—The area on the anterior surface of the thigh from which a considerable number of Small Deep Grafts have been cut. Photograph taken two days after operation. Note the rim of epithelium left between pits made by removal of the grafts. It can be seen that no material has been wasted in securing these grafts and that a large number of grafts may be obtained from a comparatively small area.

than Reverdin grafts and differ from them in that they include, in addition to the epidermis, practically the entire thickness of the corium, the thickest portion being the centre of the graft. The margins of the grafts are quite thin, but the thickness gradually increases so that at the centre the graft usually includes the full thickness of the corium. This has been verified many times by the microscope and also by the fact that the subcutaneous fat can be seen shining through the central portion of the little wounds from which the grafts are taken.

These grafts which differ in thickness from true Reverdin grafts practically as much as whole thickness grafts differ from Ollier-Thiersch grafts, should not be confused with thin Reverdin grafts and should certainly not be called Reverdin grafts.

* The work on this type of graft was largely done at the Union Memorial Hospital and, later, in the Out-Patient Department of the Johns Hopkins Hospital.

Since the publication of my paper in 1914 other reports have appeared on the same subject, and many of the authors have accepted the title "small deep grafts". Some writers, however, still do not appreciate the difference between the true Reverdin graft and the small deep graft. For example, Reverdin grafts have been described as minute plugs of full thickness skin, which is neither the description of a Reverdin graft nor of a small deep graft. Another author describes small deep grafts in a well-illustrated article and calls them Reverdin-Halsted grafts, which title is hardly correct as the grafts described are not Reverdin grafts, and, furthermore, Doctor Halsted had nothing to do with the development of this type, as the method was completely worked out before his attention was drawn to it.

FIG. 4A.—Ten days after grafting an extensive granulating wound of the buttock and thigh with Small Deep Grafts. The lesion was of thirteen months' duration before the patient came under my care and followed a severe burn. Note the halo of new epithelium from the margins of the grafts. In many places the surface is already covered with epithelium by fusion of the new epithelial growth from the grafts and wound edges. The wound was completely healed within three weeks after grafting.

At one time, Reverdin grafts were obtained by pinching up a superficial bit of skin with forceps and cutting or pinching it off with scissors, and on account of the method the grafts were called "pinch grafts". One frequently hears the term used also for small deep grafts, but there is no excuse for using it any longer, either for Reverdin grafts or small deep grafts, as the use of forceps and scissors has long been abandoned by surgeons having any respect for tissues as they cause unnecessary trauma, both in lifting and cutting the graft, and thus violate one of the fundamental surgical principles.

In 1922, Dehelly read a paper entitled "La Greffe Cutanée de Davis" before the Society of Surgery of Paris. He followed quite closely the technic used by us, and gave the results of his experience with these grafts. Active discussion followed and among the points made the following may be interesting:

Paul Thiéry and A. Schwarz said, in part, that there was nothing new about this type of graft and that the method was ancient. They also said that the grafts were identical with Reverdin grafts. P. Sebileau and P. Duval said, in part, that these grafts were the same as the dermo-epidermic grafts

of Ollier. Cunéo said that the grafts described were neither the grafts of Reverdin, which are very small epidermic grafts, nor the grafts of Thiersch, which are dermo-epidermic grafts and are characterized by their thinness. Also that the results shown do not resemble in any way those following a Thiersch graft.

Savariaud and Mauclaire said, in part, that the grafts did not merit the name of whole thickness, but were simply dermo-epidermic grafts. In answer to some of these criticisms, I would say that apparently it was not clearly understood, by those discussing the paper, that the grafts did not include the full thickness of the skin at every portion, but only in the centre.

FIG. 4B.—The same area one year later. Note the soft pliable type of healing, which has remained stable now over a period of eleven years. Note the individual grafts, each of which can be seen as a patch of normal appearing skin which is soft to the touch.

Reverdin's discovery, in 1869, that small bits of "epidermis" could be transplanted and would grow in a new field stimulated a great deal of investigation along these lines, and upon his work is based the entire structure of skin grafting as used today. As I have said before, it was while investigating and trying out his method that the thicker grafts which we call small deep grafts were experimented with, and proved so much easier to cut and gave so much more stable healing that it seemed best to use them. This method may have been used long before I began to work on it, as there is little that is really new when one goes back into the past. However, after a rather careful search, I am unable to find a report of this type of graft previous to my original paper.

Unquestionably small deep grafts are dermo-epidermic grafts, but I cannot agree that these grafts are made after the method of Ollier, my reason being the following quotation from Ollier's communication in 1872: "Instead of grafting small bits of epidermis two, three and four millimetres square as M. Reverdin does it, M. Ollier grafts large flaps of four, six, and eight centimetres square and more, including not only the superficial layers of the skin, but the whole of the derma."

From this it can be seen that there is nothing in common between the type advocated by Ollier and small deep grafts, except that the small deep grafts penetrate the full thickness of the skin at its centre. Ollier's grafts from his description were evidently what we now call full-thickness grafts. In size also they differ from small deep grafts, inasmuch as they were much larger, from four, six, and eight centimetres square, while the small deep graft should never be more than four or five millimetres in diameter.

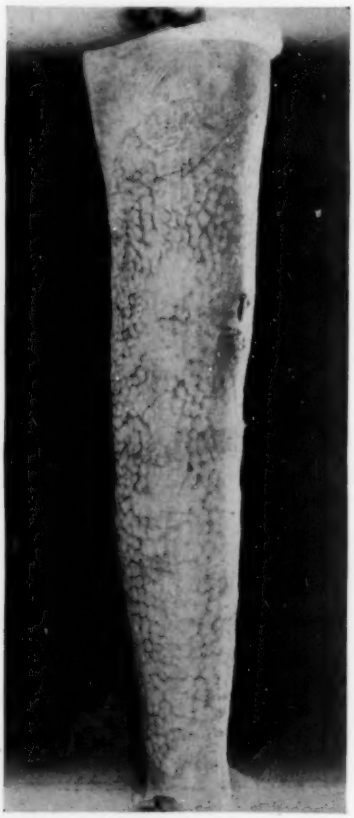

FIG. 5A.—The result of grafting an extensive granulating wound of the leg and thigh with Small Deep Grafts. The photograph was taken at the time of discharge from the hospital. On account of the magnitude of the wound two sessions were required to completely cover it. Note the individual grafts which were placed about 0.5 centimetre apart.

No one who is familiar with the subject now believes that Reverdin grafts are pure epidermic grafts. There is no question but that the appearance of a surface grafted with an Ollier-Thiersch graft in no way resembles one on which small deep grafts have been placed, but it must be borne in mind that the latter type of graft is used especially when we desire quick stable healing without special regard to appearance.

Small deep grafts most certainly do not merit the name of whole thickness grafts throughout their full extent as they include the full thickness of the skin only at the central portion, but it is obvious that they should be placed in the thick graft group.

*Classification.*—We frequently hear the terms, epidermic graft, dermo-epidermic graft and dermic graft. Is this a good classification? As it is impossible to cut a pure epidermic graft from normal skin with any apparatus now available, I feel that the term epidermic graft should be abandoned. Every type of graft actually belongs in the dermo-epidermic group inasmuch as the Reverdin graft, the Ollier-Thiersch graft, the small deep graft and the whole thickness graft all consist of epidermis with a varying thickness of the dermis. Dermic grafts actually mean whole thickness grafts and this is the only term of the three which is definite. Taking these facts into consideration, I have adopted a simple nomenclature based on the thickness of the grafts themselves and have separated them into two general types—*thin* grafts and *thick* grafts. In the *thin* group should be placed the original small thin grafts of Reverdin and the larger grafts of Ollier-Thiersch which, if properly cut, are of the same thickness. In the *thick* graft group belong the small deep grafts, and the whole thickness (Wolfe-Krause) grafts.

*Source of Grafts.*—Small deep grafts may be cut from any available portion of the skin, but where possible they should be taken from areas which are ordinarily covered by clothing, as the multiple small scars left after healing has taken place are unsightly. My preference is to use skin from the upper anterior surface of the thigh.

The region from which the graft is taken has little if any effect on the success or failure of the result, but I find that it is advantageous to take them from areas where the skin is not too thick. It is, of course, preferable to secure the grafts from the patient himself, and we can almost always find an available area of normal skin.

FIG. 5B.—The same area twelve years later. The patient has been working continuously since leaving the hospital. The skin is soft and movable over the underlying tissues. The individual grafts are still perfectly distinct and definite, and give a mottled appearance, otherwise the grafted area seems as stable as the normal skin. Note the absence of all contracture.

*Surface on Which These Grafts May Be Placed.*—These grafts may be successfully placed on a fresh wound, but ordinarily they are used on granulating surfaces. Granulation tissue suitable for grafting should be clean, firm, rose pink in color and not exuberant. There are many methods of preparing a granulating area for grafting, but I will not consider them here as each surgeon has his own ideas as to when the granulations are ready and how to prepare them. I feel, however, that I, personally, can tell more by the appearance of a granulating surface as to proper time to graft than I can by depending entirely on a bacterial count, as frequently a count may be high and the granulating surface may be clinically perfect for grafting and *vice versa*. If the appearance of the granulations is satisfactory and the bacterial count is low or negative, then we have the ideal condition, but in my own work I depend more on the appearance of the surface than on the count.

At times we are forced by circumstances to place these grafts on granulating surfaces which are not in good condition for grafting, and it is surprising how frequently they will take hold and live. In other words, small deep grafts will take on surfaces on which no other graft can survive except possibly Reverdin grafts.

*Preparation of Healthy Granulations to Receive Grafts.*—After the granulations are clean, flat and healthy, on the day preceding the grafting, a careful toilet of the unhealed surface and also of the surrounding skin should be made. The surface should then be covered with a thick, flat pad

of gauze saturated with normal salt solution and this pad should be allowed to dry out. Immediately before operation the gauze, after being thoroughly soaked with normal salt solution, is removed, care being taken not to cause bleeding, and the wound is washed with ether, followed by normal salt solution. The surface is then dried and a pad of dry gauze is placed over it and is pressed down firmly on the granulations. This gauze is peeled back just before the grafts are applied, as it is important that the surface to be grafted should be dry, but not glazed, because the grafts adhere more firmly to such a surface. The skin surrounding the granulating area may be cleaned by any method desired.

FIG. 5C.—The same leg flexed. Note the well-formed popliteal space and the hamstring tendons standing out as if under normal skin.

*Preparation of the Area from Which the Graft Is to be Cut.*—After the area is shaved, a thorough scrubbing with green soap and water, followed by alcohol and ether, is probably the best method of skin preparation. The following chemical methods may also be used with satisfaction—iodin, 2.5 per cent. several coats; 5 per cent. picric acid in alcohol; Potassio-mercurio-iodid (Kalmerid) 4 grams to 460 centimetres of acetone.

*Anæsthesia.*—Ordinarily these grafts are cut under local anæsthesia, either induced by nerve blocking or by infiltration, and the process can be carried out with very little discomfort to the patient. Infiltration seems to have little, if any, detrimental effect on the healing of the grafts, but all things being equal, nerve blocking is preferable. I do not care for massive infiltration, but to infiltrate only a small area at a time. It is seldom that general anæsthesia is used for cutting this type of graft, except in nervous children and excitable adults.

*Technic.*—Place the patient in a comfortable position on a bed or a well-padded table. With experience one can tell quite accurately the approximate area of skin required to supply the necessary grafts, and this area is marked out in the shape of a rectangle or square with five per cent. brilliant green in alcohol. It is helpful to the assistant placing the grafts to have the marked out surface from which the grafts are cut lightly stained with

brilliant green or some other dye, as then there is no difficulty in determining which is the epithelial surface. After the desired anæsthesia is induced a bit of epidermis is picked up on the point of an intestinal needle held firmly in an artery clamp and is raised so that a little cone is formed.* The base of this cone is cut through with a sharp scalpel, the blade being slightly tilted downward until the centre of the graft is reached, otherwise it will not include the full thickness of the skin. (By cutting through the tip of the cone with the blade level, we can obtain a thin Reverdin graft.) If the scalpel is made to cut toward the operator the shape of the graft is ordinarily nearly round or oval; if it is made to cut from the side, the shape of the graft is much more oblong. I usually cut the grafts in vertical rows running upward across the area marked out, and as the surface from which the grafts are cut is seldom level, it is advantageous to begin cutting each row at the lowest level, and to work upward, as in this way the field is kept clear of blood.

Properly cut grafts are preferably round or irregularly oval and vary between 0.4 and 0.5 centimetre in diameter. They are thickest in the centre, where the full depth of the skin is usually included, and taper off toward the edges where they are quite thin. There should be a narrow rim of undisturbed epithelium left between the pits made by cutting the grafts. The graft still on the needle may be transferred at once to the wound and placed with its raw surface on the granulations. If this method is used a number of clamps with needles will be necessary, each needle being flamed before it is returned to the operator, in order to avoid possible infection from the granulating area.

A simpler method and one which I now use most frequently is to dislodge the graft from the needle onto a folded towel where it is picked up on another needle by the assistant who is applying the grafts. This procedure also has the advantage of removing any blood which may be on the raw surface of the graft. The grafts should be placed in rows, raw surface down, a space of 0.5 centimetre being left between each graft, and no attempt should be made at this time to uncurl the thin edges which tend to roll under. After two or three rows have been applied a strip of rubber protective about 2.5 centimetres wide, in which "V" shaped slits have been cut, and long enough to extend well out on the surrounding skin is placed over the grafts so that the rows are covered. Then with a gauze pledget firm pressure is made directly downward on the protective and this will cause the edges of the grafts to uncurl and spread out on the granulations, and the thicker part of the grafts to come in close contact with the granulations at every point. More rows of grafts are placed and then another

* Agnew, in 1874, suggested the point of a needle to raise the bit of skin to be cut in obtaining the Reverdin grafts. It has proved a simple and saitsfactory method to use when cutting small deep grafts as it raises the cone of the skin with the least possible trauma. Agnew, D. H.: Ulcers—Skin Grafting. Med. and Surg. Rep. vol. xxxi, p. 424, 1874.

strip of protective, which is laid so that it will partly overlap the one previously applied. This procedure is continued until the desired area is covered. The ends of the protective strips are secured to the skin by means of a few drops of chloroform. Sometimes, if the area is not too large, we place the grafts over the whole surface and then press them down with a smooth gauze pledget to uncurl the edges. A douche of hot air is then played over the grafted surface for a few minutes to set the grafts, and the protective strips are applied as described above. Sometimes strips of perforated cellosilk are used instead of rubber protective and may be secured to the skin by a solution of equal parts of absolute alcohol and ether.

An excellent method of immobilizing the grafts and holding them firmly against the granulating surface is to place a thin piece of sea sponge, cut to fit the defect, immediately over the protective and over this a thicker sea sponge, which projects beyond the grafted surface, the whole being secured under even pressure by means of adhesive plaster and a bandage. I still prefer to dress these grafts with overlapping strips of rubber protective rather than to expose them to the air for a number of hours. As far as I can determine, the use of the hot air douche will accomplish in a few minutes the same result (fixation by drying) as exposure to the air for several hours, but even when this method is used it will be noted above that the protective strips are also applied.

*Dressing of the Area from Which the Grafts Are Cut.*—Silver foil is the most satisfactory dressing for the area from which small deep grafts have been cut. Several layers of foil are applied and over this the porous paper which separates the leaves. Finally a flat gauze dressing secured with adhesive plaster and a bandage. This dressing is left undisturbed for about two weeks, and when it is removed the little wounds will be healed.

*Post-operative Treatment.*—The part should be immobilized, and if necessary the patient should be kept in bed for a longer or shorter period depending on the size and situation of the grafted area. When the grafts are placed on a granulating surface the dressings should be changed after forty-eight hours; when on a fresh wound the dressing may be delayed for a week. Frequently the grafts placed on a granulating surface and dressed with rubber protective strips will be found bathed in a creamy secretion, but they seem to thrive in it. This secretion should be gently mopped off or removed by irrigation with normal salt solution. Then again apply the protective strips and a sea sponge as at the original dressing. Within forty-eight hours after grafting, those grafts which will live become a dusky pink with a deeper blotchy area in the centre. Even at this early period a narrow halo of newly-formed epithelium can often be seen around each graft. Those grafts which do not take are white in color and will come away with the dressings in the course of a few days. The grafted area should be dressed every day after the first dressing and the protective strips should be applied for the second and third dressings, but with gauze over it instead of a sea sponge. After this some bland ointment spread on old linen is useful. When

the growth of the epithelium from the graft margins seems sluggish, eight per cent. Scarlet Red ointment will often cause stimulation of the growth. Compresses of gauze saturated with normal salt solution may also be used with satisfaction after the grafts have become firmly attached. Should the spread of the epithelium be slow and the granulations between the grafts become exuberant, compresses saturated with Dakin's solution may be used after the fifth day without harm to the grafts. As soon as the newly-formed epithelium from the grafts and the wound edges has fused, stearate of zinc powder and exposure to the air are helpful. The grafted area should be protected from injury for several weeks. About three weeks after healing has taken place gentle massage should be started and should be continued until the grafted area slides easily over the underlying tissues. Desquamation of the grafted area usually occurs and continues for several months after healing has taken place. This can be easily controlled by the application of cold cream or some other bland ointment.

*Comments.*—In plastic surgery conditions frequently arise which prohibit reconstructive work until the defect is healed so that asepsis can be secured. In such instances, these grafts are most useful as they promote a rapid, stable healing with very little waste of skin.

There are four main points necessary for the successful use of small deep grafts.

1. The granulating surface should be healthy, clean, flat and rose pink in color.

2. The grafts should be cut without unnecessary trauma; should usually include the full thickness of the skin at its centre and should be no larger than 0.5 centimetre in diameter.

3. The grafts should be placed on the surface of the granulations with an interval of 0.5 centimetre between them. They should be pressed down firmly on the granulations so that the thin edges will uncurl and so that every portion of the graft will be in close contact with the granulating surface.

4. The grafts should be immobilized until the new blood supply is assured.

Small deep grafts are used more frequently on granulating wounds than on fresh wounds. It would seem self-evident that it is necessary to place the raw surface of the grafts in contact with the granulating area to be grafted, but it has been said that these grafts will take equally well whether placed with the epithelial surface up or down. This may be true if the grafts are buried under the granulations, but my experience has been that any graft placed on a granulating surface with the epithelial side down, either accidentally or on purpose, will not live. The proper cutting of a small deep graft insures its close application to the surface on which it is placed without burying it in the granulations. In other words, when a graft is applied and pressed down, the thicker central portion goes quite deeply into the granulation tissue and every portion of the raw surface of the graft, even to the thin edges, comes in contact with the bed on which it is placed.

Should we actually punch out or cut up whole thickness skin into grafts

of the same size, they would project above the surface upon which they were placed and come in contact with the wound only at their bases, thus having much less of a surface through which to receive the new blood supply. They would also be hard to immobilize unless they were buried in little pits made in the granulation tissue, which procedure has been found inadvisable, as the grafts thus buried after their blood supply is assured are likely to be smothered by exuberant granulation tissue.

Almost invariably there is stimulation of epithelium from the wound edges following the application of these grafts, and successive graftings cause successive stimulations. When small deep grafts are placed at greater intervals than 0.5 centimetre apart the granulations between may become exuberant before the epithelium from the margins of the grafts can spread enough to cover them, and thus control the growth. Grafts may in this way be overwhelmed by granulations and in some instances are completely buried. When this condition occurs, the grafts are unable to spread and are sometimes absorbed. There is often considerable difficulty in reducing granulations which have become exuberant between the grafts without injuring the grafts themselves. The epithelium from each graft will spread over an area from 2 to 2.5 centimetres in diameter if the grafts are placed quite far apart, but the healing will be more stable if they are planted with intervals of about 0.5 centimetre between them.

There is marked shrinkage in the size of the original wound after grafting with small deep grafts. Contracture may occur in an area grafted with these grafts, especially in certain situations, for example, the axilla, but it is much less marked than would occur had the area not been grafted. On account of the dotted appearance of a surface successfully grafted with small deep grafts, it is inadvisable to use them on the face and other exposed positions except in special instances. Sometimes a brownish pigmentation may form in the grafted area but this also occurs in other types of grafts. Occasionally a keloid will form between the grafts and also in the area from which the grafts are cut, and there is no way to prevent this formation or to tell when it will occur.

A large number of grafts may be cut under local anæsthesia from a very small area with little discomfort to the patient. For instance, I recently counted thirty grafts taken from an area 3½ x 3½ centimetres. When we have a large granulating surface, it is frequently impossible on account of the condition of the patient or the lack of available skin surface to cover it completely with either Ollier-Thiersch grafts or whole thickness grafts. In such a case, small deep grafts offer the solution of the problem and may be applied here and there over the surface to start islands of skin; then, in a few days other grafts are placed between those already applied and so on until the new epithelium covers the area. It is seldom that we find the granulations on a large wound all in the same condition. Some parts may be ready for grafting and others may not, so in such a case the areas ready are grafted in the routine manner, with the grafts quite close together, as

described earlier in the paper, and later the other areas are grafted when they become fit.

It has been suggested that the healing of the little wounds left by cutting the grafts may be expedited by making oval grafts instead of the rounder shape and suturing each wound. This is hardly necessary as ordinarily the healing is prompt and the appearance of the scars of a sutured group of oval pits is little better than when suturing is not done.

Certain operators cut grafts from one to one and one-half centimetres in diameter and call them either Reverdin grafts or small deep grafts, neither of which titles are correct. These large grafts are unsatisfactory for several reasons: the result is more unsightly; there is not as much epithelial proliferation possible from the margin of a single larger graft as from several smaller grafts whose total area is the same as that of the larger graft; where available skin is scanty, more is wasted than when small deep grafts of the proper size are cut, and also the resulting scars are more objectionable. Healing is much expedited by the use of small deep grafts. The difference in the stability and character of the healing obtained after grafting with thin Reverdin grafts and with small deep grafts is almost as marked as that which is found between the results of thin Ollier-Thiersch grafts and whole thickness grafts.

The results with small deep grafts are uniformly satisfactory if the granulations on which they are placed are healthy and in proper condition. There is little doubt in my mind that these grafts persist as such, as we can see the definite little patches of normal-appearing skin in the grafted area years afterward. At one time, I was able to cut some of these grafts from a tattooed area and the pigment remained in them over a period of years. Frequently, hair will grow from the deep central portions of small deep grafts, if they are cut from a hairy area.

There is little to be gained in excessive speed in cutting and placing these grafts, and I feel that better results can be obtained when the procedure is carried out with ordinary celerity and not by the stop watch. Unquestionably, it is an irksome procedure to cut and apply several hundred of these grafts at one time, and it requires much more energy than would be used in obtaining a large Ollier-Thiersch or whole thickness graft. On the other hand, we must bear in mind that these grafts can be used successfully on surfaces on which no other type of graft, except the Reverdin graft, could take; that they may effect a cure on a patient too depleted to stand the greater operative procedure required in obtaining the other types of grafts; that a large surface may be grafted from a comparatively small area of skin. The use of small deep grafts is frequently disparaged, but in most instances by those who have had no experience with the method.

It is interesting to note that since this type of graft was developed, small deep grafts have been used at the Johns Hopkins Hospital on the vast majority of routine cases which require grafting, while previously at least 95 per cent. of the cases were grafted with Ollier-Thiersch grafts.

In my own work I use small deep grafts constantly and with the greatest satisfaction. They will cause the stable healing of wounds on which Ollier-Thiersch and whole thickness grafts cannot take. In fact, I could not get along without them when dealing with large granulating surfaces and with some of the complicated problems in wound healing.

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# IMPRESSIONS RESULTING FROM THREE THOUSAND TRANSFUSIONS OF UNMODIFIED BLOOD*

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During the past ten years we have made an effort to evaluate blood transfusions—to determine what benefit our patients were receiving from the generous use of transfusions in several conditions. At times we have been overjoyed at the results obtained. At times we have been disappointed. But, nevertheless, we have emerged from this ten years of study, during which we have performed over three thousand transfusions, convinced that the transfusion of blood will always be an important and valuable adjunct; a procedure with which we would be loath to dispense or even curtail; one to be used without hesitation in the sometimes rather complicated process of curing sick patients.

In attempting to determine the value of any treatment we must sacrifice a high degree of accuracy when dealing with human beings, because we usually have no control. Animal experimentation possesses certain advantages for which we cannot hope in clinical medicine and surgery. When we say that a certain method of treatment has reduced the mortality of a certain disease we have not, as a rule, one hundred cases which have received the treatment and one hundred cases which have not.

Even if such conditions were ever available, any doctor with human impulses would probably find himself instinctively deserting the rôle of pure investigator for that of healer, especially if the disease threatened to be fatal and if the remedy promised to be effective.

Thus our clinical opinions are robbed of precision, perhaps fortunately so, because mathematical precision would soon rob us of interest and enthusiasm. So when we say that we did a certain thing for a patient and the patient recovered, someone can always ask, "How do you know that the patient would not have recovered anyway?" The answer is, "We don't." Our intelligence and experience, however, prevent too great an error in our deductions and our conclusions are fairly accurate in spite of seemingly crude methods of clinical investigation.

A fairly large series of carefully observed cases has made it possible to state positively that blood transfusion has appreciably reduced our post-operative mortality and morbidity. It has made possible the successful operation of otherwise inoperable cases.

Many surgical cases come to us with pathology which has existed for a considerable period of time often associated with infection and toxæmia, and frequently secondary anæmia, rendering that individual poorly resistant to any

* Presented at the Thorndyke Memorial, Boston City Hospital, October 10, 1928.

added insult. Metabolism has been deranged. Oxidation of the tissues has been interfered with. The biochemical equilibrium is unstable. Surgical shock is a danger—acidosis always a possibility. One or more blood transfusions before operation usually changes the prognosis by wholly or partially restoring the proper physiological balance and normal biochemical equilibrium.

After operation the same indications exist. Frequently more blood has been lost at operation than we anticipated. Besides, it has been forcibly brought to our attention that we usually have a vague idea of the amount of hæmorrhage during an operation. Often when we would estimate the amount of blood lost to be fifty or a hundred cubic centimetres, several times that amount is more nearly correct.

Surgical cases usually need medical treatment as well as surgical. This is a point we sometimes overlook. In long-standing severe secondary anæmia we can invariably benefit the patient more in a few minutes by blood transfusion than in weeks and often months of drug administration.

There is one type of case with which we are all familiar: The post-operative case which, for no apparent reason, does not "do well." We have no definite diagnosis to apply, no scientific explanation to offer. There are no positive laboratory tests, no tangible physical findings. If death intervened, the pathologist probably could not throw much light on the situation because the pathology is often chemical and therefore invisible or, at least, ultramicroscopic. A scientific or clear-cut indication for a transfusion is lacking, but experience has shown that a transfusion in this type of case will often transport the patient from the realm of uncertainty to one of normal convalescence within a few hours.

We should not look upon blood transfusion merely as an emergency procedure to be used only in an attempt to save the life of a patient. We have given blood to many patients who doubtless would have recovered without it, but whose convalescence has been satisfactorily hastened thereby. To illustrate, we may consider a case of ruptured tubal pregnancy. The patient is usually markedly anæmic with a red blood count often around two millions. We know that the prognosis is fairly good and the patient probably will recover. But altogether too frequently we see these patients three or even six months after operation still somewhat anæmic, although sometimes not, but never having fully recovered good health. We know of no adequate explanation. But we do know that with a transfusion at the time of operation their recovery is often comparable to that following a simple appendectomy. The loss of a large amount of blood entails other factors besides the mere loss of corpuscles and hæmaglobin.

In septicæmias our results with blood transfusion have been somewhat erratic, but, for the most part, satisfactory. In infection without anæmia our transfusions frequently have been supplemented by mercurochrome intravenously or protein subcutaneously. It has been, therefore, rather difficult to arrive at definite conclusions as to the value of blood in these cases,

but there can be no doubt that, while the treatment is purely empirical, improvement has often followed transfusion.

In infection with anæmia, and there usually is anæmia, there is a definite indication for transfusion. Patients with hæmolytic streptococcic septicæmia should receive a transfusion every day or every second day. A frequent question has always been, "Doctor, when do you think the patient can have another transfusion?" The answer is, "Whenever necessary." No certain space of time need elapse between transfusions. Whenever a transfusion is indicated, give it, regardless of when a previous one has been given. I mention this because at one time we all believed that considerable time should elapse between transfusions—usually about a week. We now know there is no reason for such an attitude, but we find that impression still prevailing among some of our colleagues.

The most outstanding single derangement which our patients manifest is secondary anæmia. Most of these improve and return to normal on medical treatment. The cause is removed and the patient gets well. In a few such cases, search as you will, the cause of the anæmia is not discovered and any amount of medical treatment does not change the blood picture. Many of our "chronic invalids" are merely chronic secondary anæmias, together with an accompanying anxiety and exhaustion neurosis.

From a clinical standpoint two important factors govern the success of a transfusion when the indication is acute anæmia from hæmorrhage. One is the time which elapses between the hæmorrhage and the transfusion. The other is the amount of blood given. A hard and fast rule should be: if the indication for transfusion is sudden and severe hæmorrhage, an amount of blood should be given which is, as nearly as possible, equivalent to that which has been lost, as *soon* as possible following the hæmorrhage. One outstanding fault in transfusion work in connection with hæmorrhage is failure to give large enough amounts. There are patients to whom in the past we have given 500 cubic centimetres of blood who have lost three or four times that amount. Instead of using one donor, two or three should have been used. Disappointing results are often due to failure to transfuse early enough. The transfusion is frequently thought of and then given a day or two later, often too late. We are sometimes called in consultation to give a transfusion and find a moribund patient. Inquiry reveals that there had been a severe hæmorrhage a day or two before, but the doctor had procrastinated and really got busy when death became imminent.

Hæmorrhage, or rather the resulting acute anæmia, is a form of asphyxia. Asphyxiated tissues degenerate. Prompt and adequate restoration of the blood lost will arrest generalized tissue degeneration. Acute parenchymatous degeneration of such organs as the liver and brain continued over a considerable period of time constitutes a serious disease in itself which, when other pathology is present, is not easily repaired and becomes somewhat permanent. With this line of reasoning in mind, we aim never to allow acute severe anæmia following hæmorrhage to exist for any appreciable period of time.

From the standpoint of technic several things should be insisted upon. First, the blood should not be modified in any way. No anticoagulant should be used. Of course, circumstances sometimes alter one's actions. While citrated blood is not, to my mind, equal to whole blood, yet it would be foolish to advise against the use of citrated blood where a transfusion is urgent and no other method available. We discarded the citrate method years ago because of the high incidence of post-transfusion reactions, because we did not approve of the necessary technic, and because we did not obtain as good results as with whole blood.

Secondly, the blood should remain outside of the circulation only for a few seconds. Speed has never been found to be objectionable in a transfusion—rather it is a prime requisite and the keynote of success.

Thirdly, the blood should not be unduly agitated. Stirring or shaking should be eliminated.

Fourthly, the blood should not be exposed to the air. This precaution could hardly be observed in an indirect transfusion.

And lastly, the apparatus should be so simple that anyone can easily master the technic.

A frequent question has always been, "Do you use universal donors?" We do in the majority of cases. In about one-third of our cases the patient and donor are not in the same group, and I can state positively that there is no objection to such a procedure. Such a practice does not increase the incidence of post-transfusion reactions. Our reason for preferring Group IV donors is because we are afraid to use Group II donors with Group II patients. Our most severe reactions have nearly all occurred with that combination. We believe that there are two subdivisions of Group II which are often not strictly compatible. Fewer and less severe reactions have followed transfusion in which Group IV blood was given to a Group II recipient than in any other combination in our experience.

The donor and patient should be in the same group when more than one thousand cubic centimetres of blood are to be transfused. The donor's blood, even though it possesses the necessary agglutinins to clump the patient's cells, will not do so when added to the patient's circulation in the amounts ordinarily given. Theoretically it is possible, however, to give enough blood from this donor to raise the agglutinating titre sufficiently high to cause a disturbance. Ordinarily it is only necessary that the patient's plasma does not agglutinate the donor's cells.

I have touched very lightly on the indications for the transfusing of blood. I have given you a few of my impressions received as a result of observations made in a rather large number of transfusions at this clinic over a period of ten years. In the beginning we used the Unger apparatus which we later modified. For the last three years we have used the Brines apparatus which we have found satisfactory. This apparatus provides a continuous flow of blood from donor to recipient and the possibility of stagnation and subsequent

clotting is entirely removed. The veins are entered by needless and the exposure of veins is not ordinarily necessary. The minimum of assistance is required; one assistant is necessary, but can be dispensed with. The apparatus can be used in the patient's home or at the bedside as well as in the operating room. There are no automatic spring or ball valves to become coated with fibrin rendering the valve incompetent. No mistakes can be made such as reversing the flow as arrows indicate at all times the direction of flow. No foreign substance is mixed with the blood and strict asepsis is easily

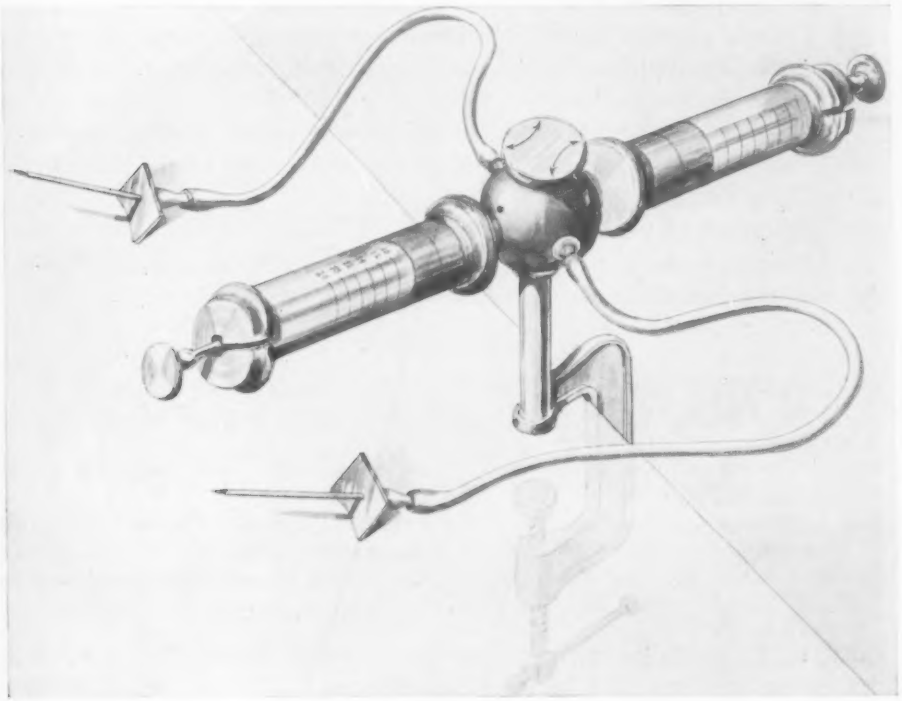

FIG. 1.—Brines' transfusion apparatus.

maintained. The blood can be accurately measured and only about five minutes are necessary for the actual transfusion. I am convinced that there is no simpler method.

We have used transfusions extensively and have been pleased with the results. We intend to use transfusions extensively in the future because we believe the procedure is worth while. There has been no mortality from transfusion in three thousand cases and in only about ten instances have we felt that the transfusion was in any degree harmful to the patient. There are few contraindications. We do not look upon blood transfusion as a panacea by any means. We usually give blood because of certain definite indications. One of the commonest reasons for transfusion in our work in the past has been a red blood count of less than three and one-half millions before operation.

## SUMMARY AND CONCLUSIONS

1. Favorable results obtained from three thousand transfusions have stimulated our enthusiasm regarding transfusions and have made us determined to extend the treatment, not only to frank anæmias, but to complicated surgical cases and bad surgical risks.

2. Even moderate anæmia before operation means prolonged and stormy convalescence after operation.

3. Severe hæmorrhage produces a deficiency of valuable blood constituents other than corpuscles and iron.

4. Chronic secondary anæmia, without apparent cause or persisting after the cause is removed, constitutes the basis of many cases of "poor health" and "chronic invalidism."

5. A simple method whereby unmodified blood can be rapidly transferred from donor to recipient should be employed and exposure of the blood to the air should be avoided.

6. Universal donors may be used safely.

7. A transfusion properly given presents practically no contraindications and produces essentially no reactions.

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# TWO CASES OF SUTURE OF STAB WOUNDS OF THE HEART

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The operative treatment of stab wounds of the heart is, and will remain, a relatively rare occurrence, but it is only relatively rare. There have been well over three hundred cases reported and it is rather curious that of this number only some fifty-odd have been by American surgeons.

As in so many other instances the application by the surgeon of well-established clinical and anatomical facts was very tardy. Block in 1882 reported the results of the surgical treatment of experimentally produced heart wounds, but in spite of this it was not until 1895 that an operation upon the human being was done. This was by Cappelan, a Norwegian. Other cases then followed rapidly until in 1926 three hundred and eleven cases were collected from the literature by H. H. Schoenfeld, who reported one at that time.

As to the operation itself, splitting of the sternum has been advised that better exposure may be obtained, but the incision most usually used is the hinge type of resection of the costal cartilages. These may or may not be replaced, at the discretion of the operator. Slightly better results have been obtained without drainage, but the tendency toward serious accumulation would suggest that the pericardium be very loosely closed if at all. Both linen and catgut sutures have been used with about equal success, but it seems obvious that in the extremely thin-walled right ventricle, and in the auricles, catgut is much superior. A doubled catgut suture is better than a single strand because of the tendency to ooze from the needle puncture. The placing of sutures so that they approximate the muscle but do not penetrate the endocardium may be easily accomplished in the left ventricle, but it is practically impossible in the thin wall of the right and probably equally so in the auricles. Its attempt might lead to untold troubles. Fortunately such a suture does not seem to be essential. Rotation of the heart should not be attempted, but lifting the heart from its bed seems to cause no disturbance and is the better method of obtaining exposure. A stay suture in the apex of the heart is almost invaluable, but must be handled with gentleness.

Reports of the two following cases in which a wound of the heart was sutured are submitted as a contribution to the statistics of the subject.

Case I.—C. P., a colored man, about twenty-five years of age, was admitted to the Good Samaritan Hospital November 3, 1928. He had been stabbed about one hour previously. He was delirious, extremely restless, his skin cold and clammy and of the peculiar ashen hue seen in the colored race when in shock. The radial pulse was only occasionally palpable and then a mere thread. At the left edge of the sternum, in the

third interspace, was a dry wound about two centimetres in length. The heart sounds were extremely distant, but clear. No definite increase in relative cardiac dulness could be demonstrated. The apex beat was absent. The lungs were clear in front and the patient was not turned to examine the backs. The temperature was 95.2° F.

Morphine was administered and while the operating room was being "set-up" an X-ray plate was made. This showed a tremendously enlarged cardiac shadow. During the two hours which elapsed between his admission and the beginning of the anæsthetic his condition improved considerably. Though still restless he was tractable and his pulse distinctly palpable with a rate of about ninety.

Under ether anæsthesia a parasternal incision was made and the third, fourth, fifth and six costal cartilages with a portion of the sternum were removed. About two double handfuls of blood clot and a considerable amount of free blood were removed from the pericardial cavity. The wound in the heart was difficult to expose because with the rotation in systole it disappeared from view. It was one centimetre long, almost vertical, and about five millimetres from the interventricular branch of the left coronary artery near its mid-portion. Apical stay sutures aided considerably in the closure of the wound with a Z-shaped catgut stitch. One stay suture was placed in the right ventricle and on removal the needle hole bled slightly, requiring a stitch to control it.

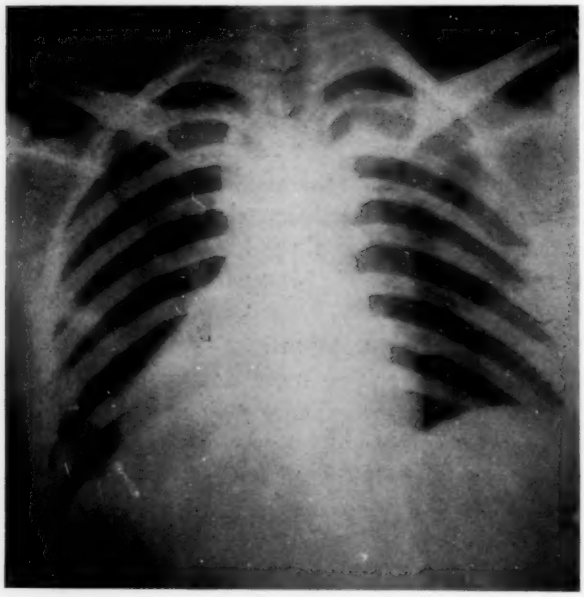

FIG. 1.—Case I. X-ray of chest showing increased cardiac shadow due to hæmopericardium.

The internal mammary artery bled freely and was ligated with difficulty because it could not be well defined. Two small perforations in the pleura were closed while the pericardial cavity was being watched for further bleeding. The heart action was irregular during the manipulations, but was quite strong when the pericardium was closed. A protective tissue drain was left with its tip just inside the pericardial wound at the lower angle. The skin and fascia were closed with silkworm gut, the cartilages having been removed.

The bleeding from the wound in the heart in this case occurred chiefly during systole and this contributed to the difficulty in locating it. In spite of a moderately large hæmorrhage about three hours after the operation, which was caused by the poor ligation of the internal mammary artery, it was not felt that there had been sufficient loss of blood to require transfusion. Six and one-half hours after operation the patient's condition had improved. The pulse, which had been 120 per minute and of poor quality on leaving the operating table, was now 106 per minute and of fairly good volume. Within twenty minutes, however, the patient died. The wound was re-opened, a very small amount of blood found in the pericardial cavity and the sutures intact. On sectioning the heart a blood clot was found wrapped around the chordæ tendineæ in the right ventricle. The post-mortem was not carried further.

CASE II.—H. J., colored, male, twenty-five years of age, was admitted December 1, 1928. He was seen by Dr. S. Watson Talbert about fifteen minutes after having been

stabbed and was immediately given half a grain of morphine, the situation being fully recognized. At that time the man's radial pulse could not be obtained, he was semi-delirious and thrashing about, and his skin was cold, clammy and ashen-gray in appearance. Thirty minutes later he was still obviously in shock, but he was quiet and his pulse while weak was of surprisingly good quality. It was markedly dicrotic, but regular, and the rate was 88 per minute. His wound, located in the third interspace, was bleeding a little. It was about 1.5 centimetres in length and vertically placed. The temperature was 94° F.

Ether anæsthesia was begun one hour and forty-five minutes after admission. A flap incision was made hinged medianward. The fourth costal cartilage had been partly severed by the stab. The third, fourth and fifth cartilages were turned back with the intercostals at the sternal edge as a hinge. The pericardium was separated from their under surface by finger dissection. A small pleural wound was closed with a single catgut stitch and the pericardium, which was easily recognized because of the typical bluish color, was incised. About two double handfuls of blood clot were removed and a considerable amount of free blood sponged away. An oblique wound in the right ventricle, nearer the apex than the base, was easily located. It was about seven millimetres in length and approximately five millimetres, or a little less, from the intraventricular branch of the left coronary artery and parallel to it. The wound bled only during diastole. One 0 chromic catgut stitch was placed and tied. This controlled most of the bleeding, but another stitch was necessary and it was placed lengthwise of the wound and at right angles to the first one because of the proximity of the coronary vessels. This suture was carefully tied with just enough tension to slightly pucker the wound and stop all bleeding. The cavity was thoroughly inspected and found dry before being closed loosely with a running catgut stitch. About one and one-half centimetres of the pericardial incision at its lower angle was left unclosed. The costal cartilages were replaced and muscle sutures depended upon to hold them. A protective drain was placed down to the injured area of the fourth cartilage.

FIG. 2.—Case I. The wound is not well seen but the sutures indicate its location and the proximity of the vessels.

The heart action was good during the entire operation, not more than half a dozen extra systoles occurring. During the operation 1000 cubic centimetres of salt solution was given by hypodermoclysis. At the conclusion of the operation the pulse was of fair quality and its rate was 100 per minute. Eleven hours later the temperature was 98.3° F. and the pulse, while still dicrotic, had a rate of only 96. The patient was quiet, rational and coöperative. He had been given one-half grain of morphine on admission, three-eighths grain immediately after operation, and one-sixth grain every three hours thereafter.

The blood pressure observations were quite interesting. Eleven hours after operation the systolic pressure was 162 and the diastolic 118 millimetres of mercury. The day after operation the reading was 142/105, and the third day 135/105.

By this time the patient had developed signs of definite pulmonary involvement over both fronts. He was not turned to permit examination of his back. He had a rather severe cough productive of fairly large amounts of green mucopurulent material.

On the fourth day the blood pressure was between 100 and 110 systolic and 70 to 80 diastolic. This indefinite type of reading was due to the fact that both the blood pressure and the pulse rate changed at intervals of from three to five minutes. By the seventh day the heart action had become quite irregular. The blood pressure was 120/80 as nearly as could be determined. Digitalis therapy was begun and resulted in a surprisingly

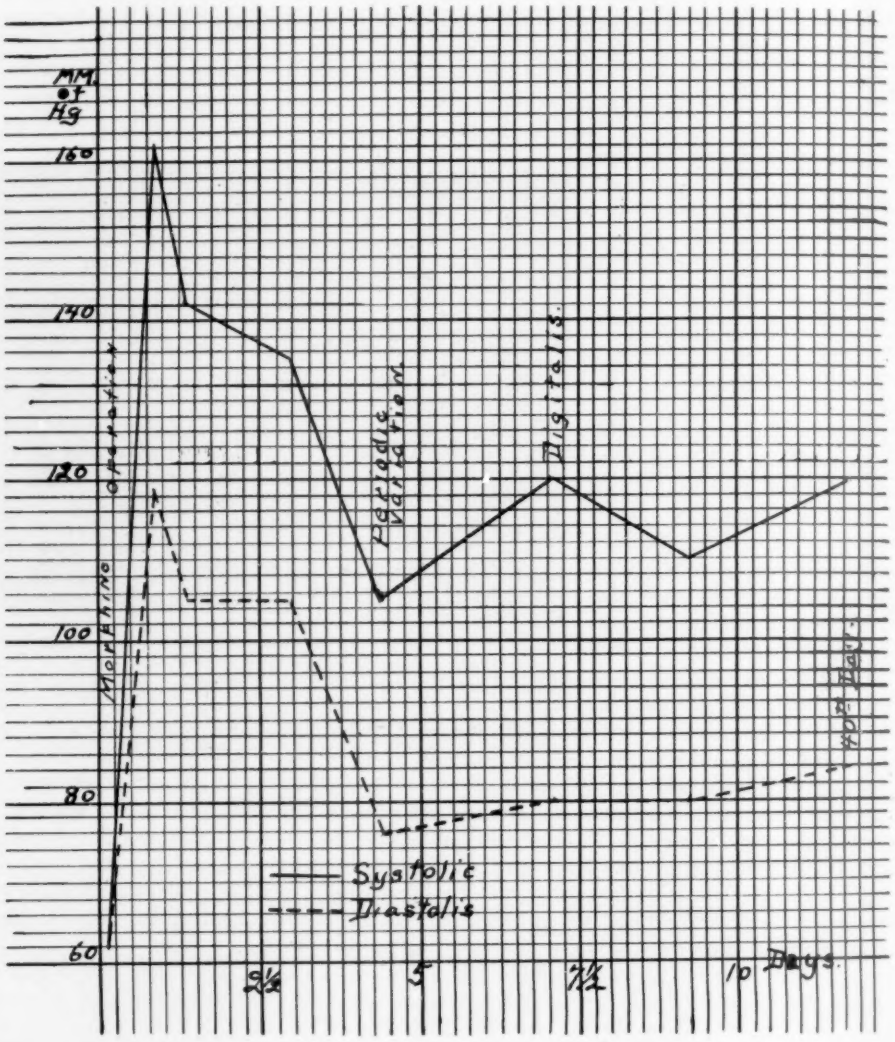


FIG. 3.—Case II. Systolic and diastolic blood-pressure graphs showing the post-operative rise in both. A somewhat similar systolic rise was observed by Beck in his experimental work on dogs.

prompt and gratifying return of the heart to its normal rhythm, and on the ninth day the blood pressure was 110/80.

A friction rub was audible over the apex on the seventh day. It soon shifted its location to the base, but did not disappear until the twenty-fifth day after operation. The lung situation cleared up very slowly. The temperature, which went above 102° F. on only one occasion, came down gradually. The wound healed cleanly except at the site of the original injury from which area a small amount of slightly cloudy, straw-colored fluid drained for some time.

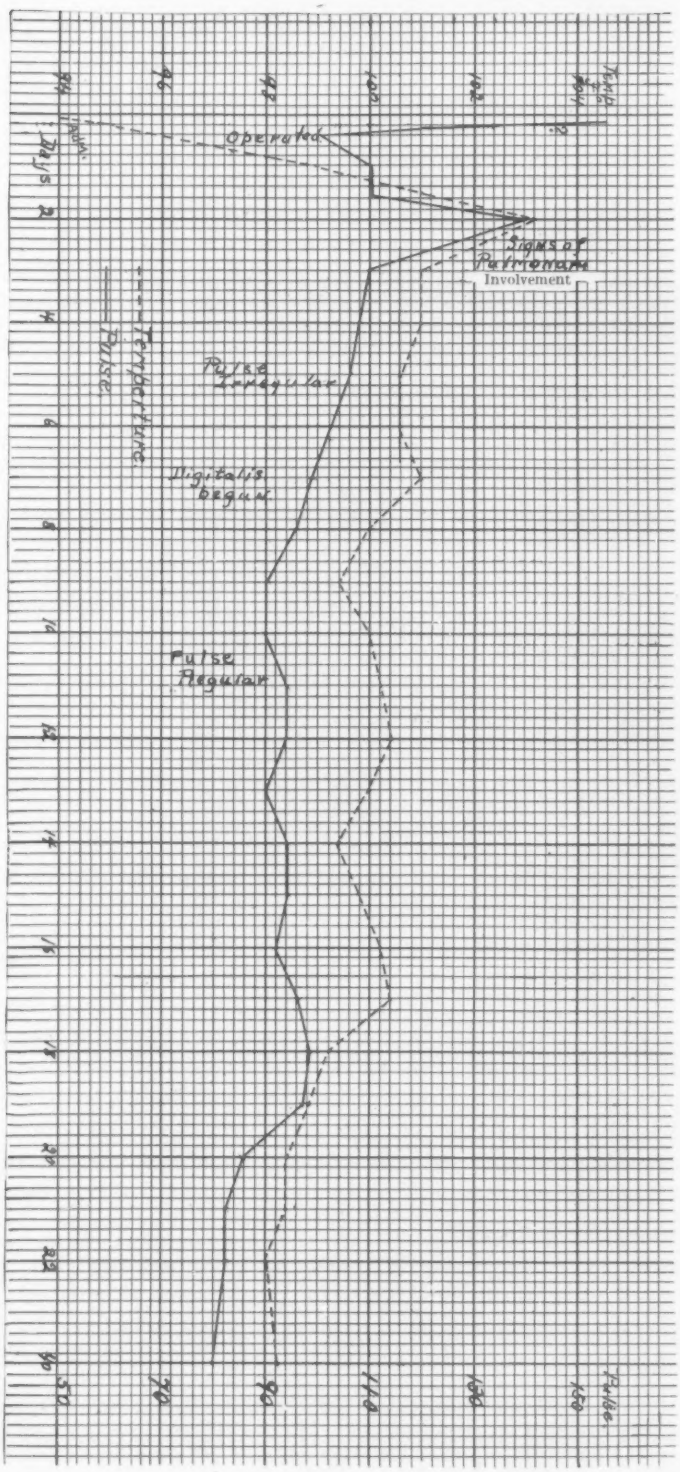


FIG. 4.—Case II. Graphs of the temperature and pulse demonstrate the spectacular fall in the pulse rate under morphine and the rise in temperature as the patient reacted from shock prior to operation.

Dr. J. Heyward Gibbes very kindly examined the patient for us on the fortieth day. He found definite evidence of an adherent pericardium, but an entirely competent heart muscle, and his conclusion was that "this should result in a progressive cardiac hypertrophy and the ultimate development of myocardial insufficiency".

These case reports give a few observed facts that I have not found mentioned in the literature and which lead into interesting fields of thought. On both occasions about two hours elapsed between admission and the beginning of the operation. Morphine was given to each and during this period of waiting they both became quiet and the pulse improved tremendously. The rate in each one at the beginning of the operation was only ninety per minute. This would seem to indicate that the cardiac distress is at first due primarily to heart shock and that the mechanical factor of tamponade has either been overestimated or does not come into play as quickly as has been supposed. The absence of delirium cordis during the operations was quite striking, for it is prominently mentioned by most authors. This falls into line with the idea of a lessening of the cardiac sensitiveness by morphia. The dicrotic character of the pulse in both cases and the rather sudden onset of arhythmia on the seventh day in the case that recovered were, most probably, simply evidences of an embarrassed myocardium. However, the changing character of the pulse and blood pressure and the post-operative hypertension are not so easily dismissed and are observations which, if previously made, have certainly not been prominently mentioned.

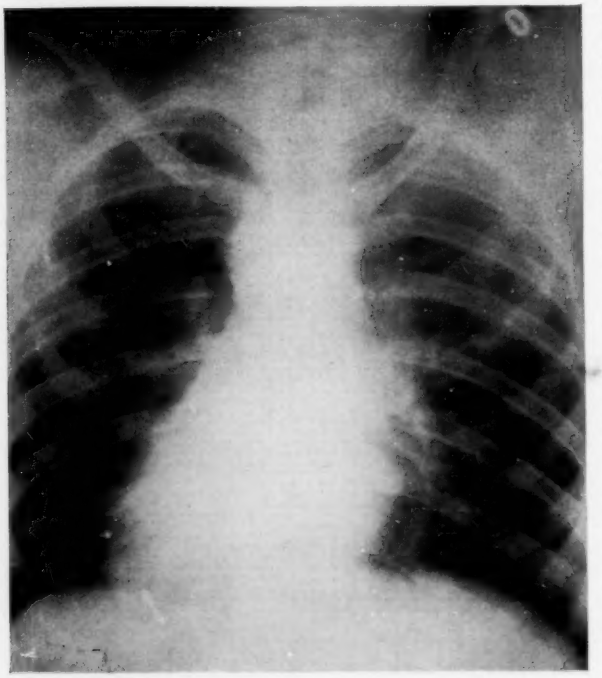

FIG. 5.—X-ray plate of chest in Case II on fortieth day. The cardiac shadow is slightly larger than normal.

Digitalis was withheld on the theory that the major portion of the heart muscle being presumably all right the drug would throw an unnecessary strain upon the sutured area, yet it had a most salutory effect when it was instituted.

The behavior of the temperature and the clinical character of the lesions in the lungs suggest that they were due to small emboli rather than to a true primary bacterial invasion, and the post-mortem findings in the first

case substantiate this. The complication is probably inherent in the lesion and deserves more consideration than it has had in the past.

If there be an outstanding conclusion that can be drawn from these cases it is that morphine, in large doses, both before and after operation, is the most important aid that we have and that even in so imperative an emergency there may yet be time to permit it to improve the patient's condition before the operation is begun.

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# END RESULTS OF SURGERY OF THE BILIARY TRACT

## A STUDY OF 634 CASES TREATED AT THE LAHEY CLINIC

By Richard B. Cattell, M.D.

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The presence of stones in the gall-bladder or bile ducts, accompanied by its frequent associated symptoms, indicates the need for surgical intervention. For the non-calculous gall-bladder there remains considerable doubt as to the best method of treatment. This can best be answered by a study of the end results following different methods of treatment in different clinics. In this paper, we have tried to evaluate our surgical results in diseases of the biliary tract, as reflected by the operative mortality and symptomatic relief over an appreciable time. This report consists of the follow-up results of 634 private patients operated upon in the Lahey Clinic from 1910 to 1926. None has been included that has been followed for less than one year, while many have been seen more than ten years after operation. No reference to the clinical symptoms nor to the etiological factors will be made in this paper, although the clinical history was used in each case to determine the end result.

The only completely satisfactory follow-up is by personal examination. We have been able to do this in approximately 40 per cent. while definite information has been received from 84 per cent. Where examination was impractical, a questionnaire was filled out. The questionnaire * used seems adequate to determine the end result. Table I shows the source of the follow-up information.

Table I.

| | |
|---|---|
| Personal examination | 235 |
| Family physician's examination | 33 |
| Questionnaire * | 161 |
| Personal letter | 23 |
| Dead (hospital and remote) | 83 |
| Record incomplete or unsuccessful | 99 |
| Total | 634 |

It is obvious that many persons who have never suffered from gall-bladder disease have some of the indirect symptoms, such as gas and belching, and we have found it necessary to go over the symptoms and condition

* QUESTIONNAIRE

1. Do you consider yourself well following your operation?
2. Have you had a recurrence of similar distress or pain?
3. Have you had jaundice since operation?
4. Do you complain of gas, belching, feeling of distention, or indigestion?
5. Have you had further operations or X-ray examinations?
6. Do you have other abdominal complaints?

found at operation to determine the end result, in order to ascertain that such symptoms were related to gall-bladder trouble.

These indefinite gastro-intestinal symptoms often alter an otherwise good result, but one cannot consider such a patient as a good result, although there is definite improvement. We have classified the results as good, improved, and unimproved. If there has been symptomatic relief, no recurrence of pain, and no incisional hernia, they were considered good results. When mild or periodic digestive symptoms persisted, possibly with discomfort or soreness in the wound without recurrence of pain or jaundice, or with post-operative hernia, they were grouped as improved. Patients suffering a recurrence of jaundice, typical pain, or the return of the pre-operative symptoms, were considered as unimproved. In the unimproved group, 10 per cent. were found in need of treatment for extra-biliary conditions, while 3 per cent. required further operation. In the 235 patients examined, fourteen post-operative herniæ were found—an incidence of approximately 6 per cent.

The classification of these patients according to the disease process is found in Table II.

TABLE II.

*Diseases of the Biliary Tract—634 Patients.*

| | | |
|---|---|---|
| Chronic cholecystitis | 181 | 28.6 per cent. |
| Cholelithiasis | 350 | 55.2 per cent. |
| Common duct stone | 52 | 8.2 per cent. |
| Cholangitis (alone) | 6 | 0.9 per cent. |
| Strictures of the ducts * | 12 | 1.9 per cent. |
| Carcinoma of the ducts | 3 | 0.5 per cent. |
| Miscellaneous | 30 | 4.7 per cent. |

The miscellaneous group includes abscess of the gall-bladder, acute pancreatitis and malignancy outside of the biliary tract requiring operations on the gall-bladder or ducts. These will be omitted from further consideration. Chronic inflammation was present in 524 gall-bladders (82.7 per cent.); acute inflammation in seventy (11.0 per cent.); while 453 (71.4 per cent.) had stones in the biliary tract. Acute inflammation was found in the presence of stones fifty-seven times and without stones thirteen times. The end results in the first group are reported with the gall-stone group, while the second have been placed with chronic cholecystitis. Ten were reported as normal by the pathologist. In each of these no other lesion was found at operation. In the group of chronic cholecystitis, seven were found to be of the so-called strawberry type. The 0.5 per cent. incidence of primary carcinoma of the ducts, exclusive of the ampulla of Vater, is higher than would be anticipated. The high incidence of stones in this series (71.4 per cent.) indicates that operation was advised usually where stones were present and was not advised for patients with chronic cholecystitis alone unless there were conspicuous clinical symptoms.

* Reported elsewhere by Dr. F. H. Lahey and Dr. R. L. Mason.

*Gall-stones.*—Gall-stones were found in 350 patients. Cholecystectomy was considered the operation of choice, and was done in 311 operations, while cholecystostomy was employed in thirty-nine. Whenever practicable, the appendix was removed at the same time. In addition, other operative procedures, exclusive of the biliary tract, were employed in fifty-five patients. The latter group we have considered separately in the follow-up figures, since it makes interpretation of the actual results more difficult. In this group of fifty-five patients, fifty had cholecystectomy, and five cholecystostomy. Table III (Part 1) shows the results in operations for gall-stones. The operative procedure in each will be considered later.

TABLE III.

*Gall-stones.*

Part 1

| | | | |
|---|---|---|---|
| Results in 295 patients | | | |
| (Cholecystectomy | 261 | | |
| (Cholecystostomy | 34 | | |
| Good | 145 | | |
| Improved | 50 | 195 | 77.7 per cent. |
| Unimproved | 26 | 26 | 10.4 per cent. |
| Operative mortality | 17 | 17 | 6.8 per cent. |
| Remote mortality (other causes) (G-7, I-3, U-2) | 12 | 12 | 5.1 per cent. |
| Patients followed | | 251 | 85.0 per cent. |
| Patients not followed | | 44 | 15.0 per cent. |

Part 2

| | | | |
|---|---|---|---|
| Results in 55 patients (Complicated by other operations) | | | |
| (Cholecystectomy | 50 | | |
| (Cholecystostomy | 5 | | |
| Good | 18 | | |
| Improved | 11 | 29 | 60.4 per cent. |
| Unimproved | 9 | 9 | 18.7 per cent. |
| Operative mortality | 4 | 4 | 8.3 per cent. |
| Remote mortality (other causes) (G-3, I-2, U-1) | 6 | 6 | 12.6 per cent. |
| Patients followed | | 48 | 87.2 per cent. |
| Patients not followed | | 7 | 12.8 per cent. |
| Complicated by pelvic operations 33, GI-16, GU-3, others 3. | | | |

From these figures it will be seen that of the 251 patients followed, 77.7 per cent. were satisfactorily relieved. This should be the case in the typical gall-stone colic patient, and, if anything, our figures are lower than would be expected. In this group there were thirty-four patients who had cholecystostomy done. As will be seen later in this paper, the per cent. of patients relieved following this operation is small. Without this group the total good results would be raised well above 85 per cent. The operative mortality of 6.8 per cent. is high, but this has dropped below one per cent. for the past two years. The operative mortality includes all hospital deaths during

the post-operative convalescence from any cause. During the one- to fifteen-years interval since operation, twelve patients died of other causes. Information from our records and the patients' physicians gave about the same relative relief in these for the interval before death: ten were relieved and two were unimproved. We have not included these figures in the percentage given, since they must necessarily be inaccurate. Table III (Part 2) shows the results in operations for gall-stones accompanied by extra-biliary operations. It will be seen that the results are much less satisfactory than for gall-stones alone, and the mortality is appreciably raised. The explanation for the poorer results lies in the fact that the typical symptoms were less frequent, and at times only the so-called silent stones were present. We have largely abandoned the practice of combining other abdominal or pelvic operations with gall-bladder operations.

*Chronic Cholecystitis.*—Chronic cholecystitis, without the presence of stones, was found in 171 gall-bladders. These include gall-bladders (1) with thickened walls, (2) those with pericholecystic adhesions, and (3) those of the strawberry type. Removal of the gall-bladder with opaque thickened walls, often with interference in function, as shown by the dye test, has yielded a high per cent. of relief and there is little doubt that it should be removed. In the few instances where the gall-bladder appeared normal but had adhesions present, relief was consistently poor. In reporting the results no division will be made. The results in these patients are found in Table IV (Part 1).

TABLE IV.

*Chronic Cholecystitis.*

Part 1

| | | | |
|---|---|---|---|
| Results in 146 patients | | | |
| (Cholecystectomy | 136 | | |
| (Cholecystostomy | 10 | | |
| Good | 52 | | |
| Improved | 23 | 75 | 64.1 per cent. |
| Unimproved | 33 | 33 | 28.2 per cent. |
| Operative mortality | 4 | 4 | 3.4 per cent. |
| Remote mortality (other causes) (G-1, I-1, U-2) | 5 | 5 | 4.3 per cent. |
| Patients followed | 117 | | 80.1 per cent. |
| Patients not followed | 29 | | 19.9 per cent. |

Part 2

| | | | |
|---|---|---|---|
| Results in 25 patients (Complicated by other operations) | | | |
| (Cholecystectomy | 23 | | |
| (Cholecystostomy | 2 | | |
| Good | 7 | | |
| Improved | 6 | 13 | 59.1 per cent. |
| Unimproved | 7 | 7 | 31.8 per cent. |
| Operative mortality | 2 | 2 | 9.1 per cent. |
| Patients followed | | 22 | 88.0 per cent. |
| Patients not followed | | 3 | 12.0 per cent. |

Complicated by pelvic operations 6, GI-13, GU-3, others—3.

The 64.1 per cent. relieved in patients with chronic cholecystitis is considerably below that of 77.7 per cent. where gall-stones were present. While it does offer a reasonable chance of relief, it makes one hesitant to operate without the presence of stones unless there be a good reason for doing so. From the experience in the clinic and from the results shown by this follow-up study, we now feel that the gall-bladder with probable chronic cholecystitis found at operation should be removed when there is a history suggesting gall-bladder disease, when the intravenous gall-bladder dye test shows or is suspicious of pathology, and where other gastro-intestinal disease is ruled out by appropriate study. If we have found sufficient indication to operate for gall-bladder disease, then we believe the gall-bladder should be removed in the absence of other pathology to account for the symptoms. In the group of thirty-three not relieved by cholecystectomy, we have been able to submit over half of them to a gastro-intestinal investigation now. Dr. S. M. Jordan and Dr. E. D. Kiefer, of the gastro-enterological department in the clinic, have found many to be suffering from functional disturbance of the colon, which in some cases probably was the chief offender during the entire clinical course.* In most of the early cases the only X-ray studies were "plain plates" for possible demonstration of stones, and, failing to show these, operation was advised on the clinical history. At the present time a patient whose clinical history suggests chronic cholecystitis without stones undergoes a complete investigation with gastric analysis, gastro-intestinal series, barium enema, the intravenous tetraiodophenolphthalein test, and when diagnosis is made cholecystectomy is done, followed by treatment directed to the colon during the post-operative period. This is followed by dietary régime after leaving the hospital. It is possible that the large number of failures in operations for chronic cholecystitis parallels the large number of failures after gastro-enterostomy for ulcer, when after either operation a patient is given no post-operative instructions. We have had no experience with the non-surgical drainage in chronic cholecystitis, but from the extensive experience of others have not felt justified in using it. Dietary treatment, or treatment directed to functional disturbance of the colon, has not shown sufficient relief in patients complaining of these symptoms to justify either alone, but, combined with cholecystectomy, seems to offer the best assurance of relief to these patients.

In the group of 171 cases of chronic cholecystitis, seven were of the strawberry type. Of these, three were relieved and three unimproved, while one was not examined. This group is too small for comment. The incidence of cholesterol gall-bladder is much higher in our later cases.

In twenty-five additional operations for chronic cholecystitis, other operations complicated the results. Cholecystectomy in these cases was often done on account of adhesions or thickening, at times in the presence of peptic ulcer. The number relieved is somewhat lower, while the mortality is again markedly raised. Part Two of Table IV shows these results.

* These will be reported subsequently.

The pathologist reported ten gall-bladders as normal when the clinical history suggested gall-bladder disease. Only seven of these were examined. Four reported themselves as relieved, while two were unimproved. There was one death. The number here is too small to justify any conclusions.

*Common Duct.*—The surgery of the common duct has been of particular interest in this clinic, and the treatment of this condition in the past two years has become much more satisfactory. Fifty-two patients (8.4 per cent.) had stones present in the hepatic or common ducts. The majority were found near the entrance into the duodenum, in the portion of the duct that frequently becomes sacular. Stones were found in the hepatic ducts in eight patients. The number of stones varied from one to thirty-two. The end results are seen in Table V.

TABLE V.

*Common Duct.*

Part 1

| Common duct stone | | | |
|---|---|---|---|
| Results in 52 patients | | | |
| Good | 25 | | |
| Improved | 3 | 28 | 62.2 per cent. |
| Unimproved | 3 | 3 | 6.7 per cent. |
| Operative mortality | 6 | 6 | 13.3 per cent. |
| Subsequent mortality due to stones * | 5 | 5 | 11.1 per cent. |
| Remote mortality (G-2, U-1) | 3 | 3 | 6.7 per cent. |
| Patients followed | | 45 | 86.5 per cent. |
| Patients not followed | | 7 | 13.5 per cent. |

Part 2

| Cholangitis | | | |
|---|---|---|---|
| Results in 6 patients | | | |
| Good | 5 | | |
| Improved | 0 | 5 | 83.3 per cent. |
| Unimproved | 0 | | |
| Operative mortality | 1 | 1 | 16.6 per cent. |
| Patients followed | | 6 | 100.0 per cent. |

In the thirty-one patients surviving operation, twenty-eight (90 per cent.) were satisfactorily relieved. The three patients who had a recurrence of symptoms gave a clinical history again of common duct stones, while one of them had recurrence so soon after operation that we felt sure the stones had been left; three stones were removed at a subsequent operation. Such experiences have made us very careful in the exploration of the common duct. We will discuss this under the heading of choledochostomy. The presence of common duct stones is a very serious thing, as shown by the operative mortality of 13.3 per cent. We will be able to show later that this is not due to the technical difficulty of opening, exploring, and draining of the duct. The deaths were usually due to liver failure or so-called "cholemia," associated with high temperature, shock, and at times with urinary retention.

* Deaths after leaving the hospital.

Although the great increase in coagulation time in deeply jaundiced patients may cause post-operative hæmorrhage and be a cause of death, hæmorrhage has not been a complicating factor in our six deaths. An important thing in this group is the occurrence of five deaths during the subsequent years after leaving the hospital, each apparently due to common duct stones either left at operation or to stones recurring in the ducts. This subsequent related mortality of 11.1 per cent. (five deaths) brings the total mortality to approximately 25 per cent. during the entire period. This high operative and subsequent mortality in common-duct-stone patients indicates to us that something must be done to lessen its occurrence. It is best accomplished by the early removal of all gall-stones. Thus it seems, with rare exceptions, all gall-stones, whether silent or causing clinical symptoms, should be removed, preferably by cholecystectomy.

Six patients showed dilatation, thickening, and acute inflammation of the ducts, at times associated with gross changes in the liver. In these no stone was demonstrated, although it is conceivable one might have been passed into the intestine. The criterion of diagnosis of cholangitis in these six patients has been jaundice, fever, pain in the right upper quadrant, without the presence of stones. The mucosal lining of the duct shows injection and the wall is thickened. These have been explored and drained for a long period of time, from fourteen days to three months. Some patients have been discharged from the hospital with a tube still in the wound. This tube can then be removed at a later visit. In one patient the ampulla was so large that the finger could be passed readily into the duodenum and there was obviously ample opportunity for regurgitation of duodenal contents. This patient became well after prolonged drainage and is now well after three years. The results are seen in Table V (Part 2). While there is frequent disappointment in the failure to find more pathology at operation, it is a satisfaction to know that these patients are usually relieved by prolonged drainage of the common duct.

*Type of Operation.*—Cholecystectomy is the operation of choice for either chronic or acute cholecystitis or for gall-stones, except in the very poor risk. During the early part of this fifteen-year period, drainage of the gall-bladder was done frequently, but has rarely been done during the past five years. The type of operation performed on these patients is shown in Table VI.

TABLE VI.

| | | |
|---|---|---|
| Cholecystectomy | 460 | 548 |
| Cholecystectomy and choledochostomy | 88 | |
| Cholecystostomy | 64 | 65 |
| Cholecystostomy and choledochostomy | 1 | |
| Choledochostomy | 7 | 96 |
| Coincident surgery at operation: | | |
| Appendectomy | | 190 |
| Gynæcological | | 42 |
| Gastro-intestinal | | 17 |
| Urological | | 4 |
| Ventral Herniæ | | 7 |

There were fifty-two patients who had two operations on the gall-bladder or ducts: of these, twenty had their first operation elsewhere, while thirty-two were previously operated upon by us. Five patients required three operations. Follow-up information was obtained a year or more after the last operation in twenty-eight of these patients. In this group, twenty were relieved, four unimproved, and four died operative deaths.

In Table VI it will be seen that sixty-five cholecystostomies were done. Twenty-two of these returned to us suffering from a return of symptoms. Five we were unable to follow, but we know that none of the remaining thirty-eight patients was operated upon elsewhere.

Table VII shows the end results found in sixty-five cholecystostomies. Of the forty-four patients followed who were not subjected to a second operation, thirty-four were done for gall-stones and nine for acute and chronic cholecystitis. The elapsed time from operation to the return of symptoms in the twenty-two patients again submitted to operation varied from immediately after operation to twelve years. One required a second operation two months after the first, six during the first year, two after two years, two after four years, four after five years, five after seven to twelve years, while in two the time was not stated. The function of a gall-bladder after cholecystostomy as determined by the dye test is definitely interfered with. This can at least partially account for the poor results. The results following cholecystostomy are further shown to be poor by the fact that twenty patients came to us with a return of symptoms, having had this operation performed elsewhere.

TABLE VII.

*Cholecystostomy.*

| | | |
|---|---|---|
| *Results in 44 Patients not Subjected to Second Operation* | | |
| Good | 14 | |
| Improved | 3 | 17 |
| Unimproved | 18 | 18 |
| Dead | 3 | 3 |
| *Summary of 65 Cholecystostomies* | | |
| Patients improved | 17 | |
| Patients unimproved and dead | 21 | |
| Patients having second operation | 22 | 43 |
| Patients not followed | 5 | |

It will be seen that of the sixty patients examined, forty-three, or 71.7 per cent., had a recurrence of symptoms, while only 28.3 per cent. were relieved. This is not a creditable showing for cholecystostomy. It is generally accepted at the present time that cholecystostomy does not give as good results as cholecystectomy. This is borne out by these figures.

*Choledochostomy.*—We have found exploration of the common duct a frequent necessity in biliary surgery. During the past two years the incidence has greatly increased. This incidence of duct exploration is seen in Table VIII.

TABLE VIII.

*Choledochostomy.*

| | | |
|---|---|---|
| | 179 choledochostomies in 909 operations .... | 19.7 per cent. |
| 1910–1926 | 96 choledochostomies in 634 operations .... | 15.1 per cent. |
| 1927–1928 | 83 choledochostomies in 275 operations .... | 30.2 per cent. |
| 1910–1926 | 52 common duct stones in 634 operations .. | 8.2 per cent. |
| 1927–1928 | 33 common duct stones in 275 operations .. | 12.0 per cent. |

It will be seen that one-fifth of all operations (1910–1928) on the biliary tract had exploration of the duct, while approximately one-third have had it done in the past two years. These figures are of particular interest, since in the period from 1910 to 1926, 15.1 per cent. of all patients operated upon had their common duct explored with the result that 8.2 per cent. of all showed common duct stones, while in 1927 and 1928, 30.2 per cent. of all patients had the duct opened, with 12 per cent. showing common duct stones. This shows that by doubling the frequency of opening the common duct the incidence of common duct stones in our cases is raised 50 per cent. We now feel that all common ducts should be opened, explored and drained which show any of the following points: dilatation, thickening, pancreatitis, presence of stones, or history of jaundice. Doctor Lahey has pointed out the not infrequent occurrence of stones in a duct which appeared and felt normal in a patient who gave no history of jaundice.

Stones were found in approximately one-half of all the ducts explored. This means that a large proportion of the remaining one-half were opened and drained that did not require this drainage for recovery, since only six were shown to have a definite inflammatory condition present in the duct itself. There are other causes of dilatation of the bile ducts exclusive of stones. Dilatation is known to occur after cholecystectomy. In approximately 20 per cent. of all the cases of gall-stones in this series, stones blocked the cystic duct. It is probable that this can produce dilatation, similar to cholecystectomy, since the gall-bladder may be actually shut out of the biliary system.

It may be thought that raising the incidence of exploration of the common duct may increase the operative mortality and the incidence of strictures. This is not the case. There has been no death in the past two years in which choledochostomy was done and no stones found. In the past eighty-three consecutive explorations of the duct we have had two deaths.

The first was a man sixty-one years of age, with a penetrating gastric ulcer which responded to medical treatment. One year later he became jaundiced and had colicky pains in the region of the gall-bladder. At operation, under spinal anæsthesia, innumerable small stones were found in the gall-bladder and four stones were found in the common duct. Wound rupture occurred on the seventh day post-operatively, and although resuture was done with regional anæsthesia, he died two days later. The second death occurred in a woman forty-two years of age. At operation, under

spinal anæsthesia, the stones from the gall-bladder had ulcerated into the liver. Three faceted stones similar to those in the gall-bladder were found at the ampulla of the common duct and two others in the hepatic duct. She died ten days later and necropsy showed an extensive acute hæmorrhagic pancreatitis. It does not seem that the technical side of opening the common duct in these two patients was responsible for these deaths. There has been no patient in the past two years that showed persistence of jaundice or symptoms of stricture after drainage of the common duct, exclusive of primary stricture cases. From this experience we do not believe that the mortality is raised nor is the incidence of stricture increased by exploration of the common duct, properly done.

In this series of 179 choledochostomies, drainage has been done with a T-tube in all but four instances, and in these a catheter was used. Primary closure of the duct without drainage has not been practiced.

*Operative Mortality.*—In the period before 1927, the operative mortality (5.7 per cent.) was excessive. During the past two years it has dropped below one per cent. This considerable reduction in mortality seems due to a number of factors. During this latter period increasing attention has been paid to the preparation before operation. A high fluid intake has been insured by the subcutaneous and intravenous administration of fluid. Glucose was given in the same manner. This is important since there is frequently interference with the glycogen supply in the liver. The renal function was more closely estimated. The time of operation was coincident with subsiding jaundice when possible. The increased coagulation in the jaundiced patients was brought nearer normal by intravenous calcium chloride. Blood tranfusion has been used to improve coagulation and to combat shock. Extra-biliary operations combined with the operations on the gall-bladder have largely been abandoned. Quite probably patients have been coming to surgery earlier in the course of the disease and because of refinements in diagnosis earlier operation has been advised. Improvements in post-operative care have added to the ease and rapidity of convalescence. Finally, a very important factor in reducing mortality has been the employment of controllable spinal anæsthesia. This has been used in nearly all cases during the past year. In the first part of Table IX, the operative mortality of the past two years is contrasted with the period before 1927. In the second part of the table, the strictures, complete external biliary fistulæ, and malignancies of the ducts are listed.

Nearly one-half (eighteen) of the deaths resulted from surgical shock. Of these, six died after extensive operations for common duct stones in the presence of long-standing jaundice. The damage of the liver in these is probably an important contributory factor. Four patients died as a result of fatal pulmonary complications, with pneumonia and pulmonary embolism each occurring twice. Pulmonary complications after gall-bladder operations are reported between 1 and 3 per cent. The total incidence here has not been determined, but this fatal incidence of 0.4 per cent. is below the expected

figure. Acute pancreatitis was found at autopsy twice when there was no evidence of such a process at operation. Each time it occurred after common duct operations for stones. This finding indicates a relation between obstruction of the common duct by stones and acute pancreatitis.

TABLE IX.

*Biliary Tract Operations—Operative Mortality.*

| | | |
|---|---|---|
| 1910–1926 | 615 operations with | 35 deaths.....5.7 per cent. |
| 1927–1928 | 275 operations with | 2 deaths.....0.7 per cent. |
| 1910–1928 | 890 operations with | 37 deaths.....4.2 per cent. |
| | 12 operations for stricture | 2 deaths.....16.7 per cent. |
| | 2 operations for complete external biliary fistula | 0 death |
| | 5 operations for carcinoma of ducts | 2 deaths.....50.0 per cent. |
| 1910–1928 | 909 operations with | 41 deaths.....4.5 per cent. |

An analysis of the cause of death in these forty-one cases is shown in Table X.

TABLE X.

| | |
|---|---|
| Operative Mortality | 41 |
| Surgical shock | 18 |
| Myocardial failure | 5 |
| Pulmonary embolism | 2 |
| Pneumonia | 2 |
| Acute pancreatitis | 2 |
| Peritonitis | 1 |
| Intestinal obstruction | 1 |
| Wound rupture | 1 |
| Not determined | 9 |

In summary, the end results in the important groups are given in Table XI.

TABLE XI.

*Biliary Tract Operations.*

*Summary of End Results up to 1927*

| | Satisfactory | Unimproved | Operative Mortality |
|---|---|---|---|
| Gall-stones | 77.7 per cent. (195) | 10.4 per cent. | 6.8 per cent.* |
| Gall-stones complicated † | 60.4 per cent. ( 29) | 18.7 per cent. | 8.3 per cent. |
| Common duct stone | 62.2 per cent. ( 28) | 6.7 per cent. | 13.3 per cent.<br>11.1 per cent.‡ |
| Cholangitis | 83.3 per cent. ( 5) | | 16.7 per cent. |
| Chronic cholecystitis | 64.1 per cent. ( 75) | 28.2 per cent. | 3.4 per cent. |
| Chronic cholecystitis complicated † | 59.1 per cent. ( 13) | 31.8 per cent. | 9.1 per cent. |

* The per cent. not followed is not stated.

† Results complicated by extra-biliary operations.

‡ Subsequent mortality due to recurrence.

## SUMMARY AND CONCLUSIONS

1. Cholecystectomy is the operation of choice for gall-stones and for acute and chronic cholecystitis, and should be done except in the very poor risk.

2. Cholecystectomy gives relief in a high percentage of patients with gall-stones.

3. Less than 30 per cent. of patients in this series having cholecystostomy have been relieved over a long period of time.

4. The operative treatment for the non-calculous gall-bladder is not satisfactory except where there is definite pathology present and conspicuous clinical symptoms associated with it.

5. The mortality after gall-bladder operations is shown to have been appreciably increased by doing other abdominal and pelvic operations at the same time. Such practice should be discouraged.

6. The operative mortality in patients with common duct stones is high. In addition, a considerable number operated upon for this condition have recurrence of symptoms, which results in a high subsequent non-operative mortality.

7. The early removal of gall-stones will reduce the incidence of common duct stones, and for this reason should be urged.

8. The mortality after operation on the gall-bladder alone is very low. In the past two years no death has resulted after such an operation.

9. Two deaths have occurred in the past 275 consecutive operations on the gall-bladder and ducts, exclusive of malignancy and stricture. Both were in patients with common duct stones.

10. The operative mortality after operations on the biliary tract has been reduced during the past two years.

11. By increasing the incidence of common duct exploration from 15 per cent. to 30 per cent. of all patients the incidence of common duct stones has been raised from 8 per cent. to 12 per cent.—an increase of 50 per cent.

12. It is obvious that exploration of the common duct should be done more frequently than is generally practiced.

13. In gall-bladder operations, the mortality is not raised nor is the incidence of stricture increased by exploration of the common duct, properly done.

14. There is a group of patients with symptoms commonly attributed to the gall-bladder, whose symptoms are due to functional disturbance of the colon. These patients respond to treatment directed to the colon.

15. Failure to obtain relief after operation for chronic cholecystitis is usually due to incomplete or wrong diagnosis.

# TREATMENT OF BILIARY FISTULA BY DIRECT IMPLANTATION OF THE TRACT INTO THE FIRST PORTION OF THE DUODENUM

By Hugh Williams, M.D.
and
Reginald H. Smithwick, M.D.
of Boston, Mass.

Reconstructive operations on the biliary tracts are comparatively common today. Implantation of the tract of a biliary fistula into the intestinal tract has been performed by Lahey,[1, 2] Masson,[3] Lilienthal,[4] St. John,[5] and Walters.[6, 7] The following case is being reported because, as far as is known, it represents the first successful anastomosis between the duodenum and the tract of an external biliary fistula. Over fifteen years have elapsed since this operation was performed. The patient is at present living and well and normal in every respect. He is now twenty years old and is in his second year at Law School. Up to a year and a half ago, the patient had occasional gastro-intestinal upsets, which were completely relieved by an appendectomy with drainage, at that time for acute appendicitis. In this case, the scar tissue tract was implanted directly into the first portion of the duodenum. The anastomosis consisted of two layers of sutures, the inner of catgut and the outer of silk. No rubber tube was employed. The wound was drained. It healed promptly, without leakage of bile. There have never been any signs or symptoms to suggest either stricture or ascending infection of the biliary tract since the operation was performed.

Case.—The patient was a moderately well-developed boy, four years of age, who was admitted to the Children's Medical Service of the Massachusetts General Hospital for the first time August 28, 1912, with a diagnosis of mesenteric tuberculosis.

*Family History.*—Negative. *Past History.*—Full term difficult delivery. Birth weight, six and three-eighth pounds. Breast fed for seventeen months. Measles five months ago. Tonsillectomy in Out-Patient Department following this.

*Present Illness.*—Abdominal tumor; recognized for two months. During the past two years patient has had four to six attacks of vomiting. For the past two weeks the condition has been distinctly worse. There has been anorexia, night sweats, fever, distention of the abdomen and loss of weight. Patient has been fretful and easily irritated. Has recently had a slight non-productive cough.

*Physical Examination.*—Normal development of body framework; rather poor musculature; fair state of nutrition. The general physical examination was negative, with the exception of the abdomen. The liver dulness began at the upper border of the second rib and extended one centimetre below the right costal margin. Spleen enlarged and felt one centimetre below left costal margin. In the right upper abdomen, between the costal margin and the iliac fossa, was a visible tumor. The percussion note over this was of a reduced tympanitic quality. The mass had a soft fleshy feeling, was difficult to outline but seemed to be distinct from the liver and corresponded more to the position of the right kidney, greatly enlarged. The mass was not tender, had no pulsation, and did not move with respiration.

*Laboratory Findings.—Blood.*—Hæmoglobin 75 per cent. White blood corpuscles 12,700. Differential count: Polymorphonuclear leucocytes 66 per cent., lymphocytes 26 per cent., transitional cells 6 per cent., basophiles 2 per cent. *Urine.*—Light yellow, clear, acid, specific gravity 1.022, albumin 0, sugar 0, sediment—occasional granular cast. Renal function test—(phenolsulphonephthalein). No appearance of dye in urine at end of one, two, and ten hours. *Stool.*—Brown, homogenous. Microscopic examination negative. *Skin.*—Turberculin test negative at end of thirty-six hours.

The patient was seen by several consultants and was transferred to the Genito-Urinary Service on September 2, 1912, with a diagnosis of embryonic tumor of the right kidney. During his stay in the hospital his temperature had fluctuated between 98.8° and 100° F.

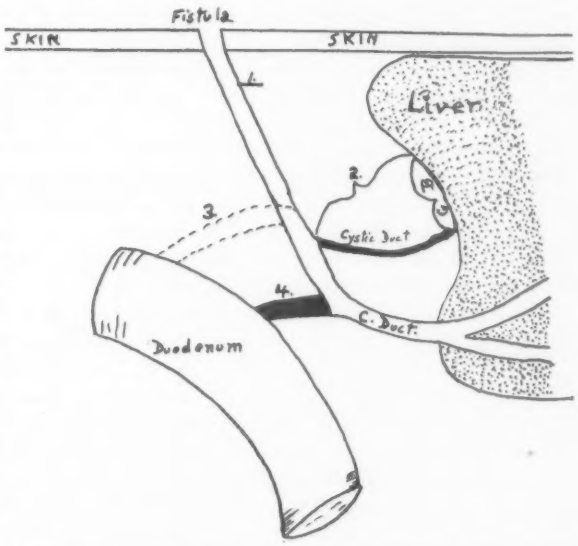


FIG. 1.—Diagram to represent the biliary tract in the case reported. 1. Tract cut off here. 2. Gall-bladder and cystic duct excised. 3. Tract implanted into duodenum. 4. Obliterated lower end of common duct.

*Operation.*—September 3, 1912.—*Exploration and drainage of cyst of liver* by Dr. Hugh Cabot. Under ether anæsthesia a five-inch transverse incision was made just above the umbilicus, extending into the right flank. Peritoneum opened with the exposure of a cystic tumor the size and general shape of a grapefruit. It was covered by peritoneum and the ascending colon was adherent to its inner surface. Above, it was connected to the liver by strong bands containing fair-sized blood vessels. Posteriorly the tumor was attached to the deep structures and could not be explored. Superiorly, a prolongation of the cyst extended upwards behind the liver. The gall-bladder appeared normal. The right kidney was normal. The peritoneum was stripped off the anterior surface of the cyst. Cyst opened with the escape of a pint or more of greenish, slightly viscid fluid. Cyst wall lined with smooth epithelium. Exploration of posterior wall of cyst from within made it seem unwise to attempt removal. As much of the cyst wall as possible was cut away. The cut edge sutured to the peritoneum, and the cavity packed with an iodine wick. Peritoneum, muscles, fascia, and skin closed on either side of the cyst. Patient sent to ward in good condition.

The patient remained in the hospital for eighty-one days, when he was discharged to the Out-Patient Department relieved. He drained bile profusely from the sinus made at operation. The stools became clay colored twelve days after operation and remained that way, occasionally showing a slight trace of bile. The child gradually went down hill for seven weeks, during which time he developed a pharyngitis, followed by cervical adenitis and bilateral otitis media. Both ears were drained. He then slowly picked up, under careful medical treatment, and was in fair condition at the time of discharge, although draining essentially all of his bile from the sinus.

*Pathological Report.*—Tissue removed at operation has the structure of a gall-bladder with inflammatory changes in the walls.

*Reëntry I.*—May 7, 1913. Since discharge from hospital five and one-half months ago, patient has done very well until five weeks ago. Attended the Out-Patient Depart-

ment regularly and took bile by mouth. The sinus continued to drain freely and the stools contained little bile.

During the past five weeks, the sinus has stopped draining several times. On each occasion, the child became ill, nauseated, constipated, and ran a temperature. With reëstablishment of draining the symptoms rapidly disappeared. Occasionally the drainage from the sinus was bloody in character. For several days before entrance, patient has had a temperature of 103° F. to 104° F. This afternoon vomited a large amount of black material and had a loose black bowel movement. Felt very weak after this.

*Physical Examination.*—Essentially unchanged except for marked pallor of skin. Several ecchymotic areas on extremities. Liver dulness within normal limits. Spleen not felt. Operative scar four inches long with a sinus in centre from which bile drains freely.

*Laboratory Findings.—Blood.*—Hæmoglobin thirty-five per cent., clotting time four and one-half hours. *Urine.*—Normal. *Stool.*—Strongly positive guaiac test, tarry in color.

May 8, 1913, patient was transfused by anastomosing the donor's radial artery to a vein in the patient's arm. Blood flow allowed to continue for forty-five minutes. Hæmoglobin following transfusion ninety per cent. Clotting time, five minutes. The tendency to bleed disappeared. The daily amount of ox gall by mouth was gradually increased from twelve to sixty grains. The patient gained steadily in weight, health, and strength and in seven weeks was considered in satisfactory condition for operation on his persistent and complete biliary fistula.

*Operation.*—June 25, 1913.—*Cholecystectomy and choledochoduodenostomy* by Dr. Hugh Williams. Under ether anæsthesia a circular incision was made about the old sinus and the abdomen opened by excising the old scar. There were many omental adhesions to abdominal wall in the vicinity of the fistula and many adhesions about the tract itself. Separation of these adhesions revealed an hour-glass gall-bladder about the size and shape of a large double peanut, with its cystic duct entering the fistulous tract about one and one-quarter inches below the abdominal wall. Gall-bladder opened and found to contain clear mucus. The cystic duct could not be probed from either end. The gall-bladder and cystic duct were removed, the duct being tied with fine silk. Adhesions further separated about the fistulous tract, and this was found to be continuous with the common duct, which was not particularly enlarged. Probe easily passed down the fistula, up the common duct and into the hepatic ducts. The duodenum was normal and lay nearby. There was a prolongation of the common duct to the duodenum, but it could not be probed and was apparently obliterated. An intestinal clamp was applied longitudinally to the duodenum, the gut opened one-quarter inch, and an anastomosis made between the end of the fistulous tract and the side of the duodenum. An inner layer of No. 0 plain catgut and an outer layer of fine continuous silk were used. A Miller wick was placed to the site of the anastomosis and the wound closed in layers.

The patient made an excellent recovery, and stools passed the following day contained a large amount of bile. The convalescence was uneventful and patient left the hospital in forty days, in very good condition. The abdominal wound was well healed and the stools were normal in character.

*Reëntry II.*—May 28, 1919. Since discharge from hospital, August 4, 1913, patient was perfectly well until two years ago. Since that time has had frequent attacks of epigastric and lower abdominal pain, associated with vomiting and fever. Bowels have moved regularly and stools have been normal in character.

June 2, 1919, a negative gastro-intestinal series was obtained and patient was discharged June 5, 1919, with diagnosis of post-operative adhesions.

*Reëntry III.*—February 19, 1927. Since last entry patient has been well with the exception of intermittent attacks of sharp colicky pain throughout the abdomen, with no definite localization. The pain did not radiate and was always accompanied by vomiting. Yesterday morning, at 2 o'clock, patient was awakened by pain in his right lower quadrant which was severe and colicky in character. Vomited once, almost immediately.

The pain and nausea has continued and his local doctor sent him to the hospital with a diagnosis of acute appendicitis.

*Physical Examination.*—Marked tenderness and moderate spasm over lower third of right rectus muscle. Tenderness on right side of pelvis by rectum. Temperature, 100.4 R.; white blood cells, 14,000. *Urine.*—Negative.

*Operation.*—February 19, 1927. Under ether anæsthesia a right rectus muscle splitting incision was made because it was felt that there would be less difficulty should adhesions from previous operation be present. An acutely inflamed appendix lying in the right side of the pelvis was removed. There was a small amount of pus about the tip of the appendix. Appendix removed, stump invaginated, and a Miller wick inserted to the point where the tip of the appendix had lain. Wound closed in layers.

Patient made an uneventful recovery and was discharged on the fourteenth day cured.

*Pathological Report.*—Appendix 5.5 centimetres in length. It is swollen, injected and the walls are œdematous. Acute appendicitis.

## CONCLUSIONS

1. The tract of a biliary fistula may be implanted directly into the first portion of the duodenum.

2. This procedure is particularly indicated in cases where the lower end of the common duct is obliterated or difficult to locate.

3. The biliary system may function normally for many years (fifteen) after such an operation without evidence of stricture or ascending infection of the ducts.

4. Feeding large amounts of ox bile by mouth was found to be an effective method of controlling hæmorrhage in this case. It has subsequently been found of benefit in reducing hæmorrhage in cases of obstructive jaundice, suggesting that absence of bile from the intestinal tract is related to the bleeding tendency of cases of complete biliary fistula and obstructive jaundice.

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# TRANSACTIONS

OF THE

# PHILADELPHIA ACADEMY OF SURGERY

STATED MEETING HELD FEBRUARY 4, 1929

DR. JOHN H. JOPSON in the Chair, DR. CALVIN M. SMYTH, JR., Recorder

## NEPHRECTOMY FOR UNILATERAL POLYCYSTIC KIDNEY

DR. A. B. THOMAS reported the case of a woman, married, thirty-one years of age, who was admitted to the Presbyterian Hospital on account of an increasing tumor in the left loin. Formerly had to rise once during night to urinate. Had gained sixteen pounds in weight the last few months. Urine: amber, specific gravity 1.018, no albumin, no sugar, no casts, no red blood cells, average two to four white blood cells per high power field, many epithelial cells. Blood count: red blood cells 4,760,000; white blood cells 8500; polymorphonuclear leucocytes 60 per cent., small lymphocytes 28, large lymphocytes 8, transitionals 2 per cent., eosinophils 2 per cent. There was no hypertension. There was an exophthalmic goitre, which had been present for six months, and a large tumor in the left loin which was thought to be kidney.

FIG. 1.—Unilateral Polycystic Kidney removed by nephrectomy.

Cystoscopy revealed a normal bladder and normal ureteral orifices. Indigocarmin given intramuscularly appeared from the right side in seven minutes and from the left side in eight minutes, but only about one-fourth the amount on the left side as compared with the right, and less intensely colored blue. Ureters were catheterized and the urine obtained revealed a few red blood cells and white blood cells from each side.

A left nephrectomy was carried out on September 9, 1915, delivering a large polycystic kidney. An abdominal incision was first made. The tumor definitely seemed to be the kidney; the opposite kidney was palpated and no evidence of cystic degeneration noted so that wound was closed. Then a lumbar incision was made and the nephrectomy carried out extraperitoneally. The patient made an uneventful recovery. A letter from her physician dated November 22, 1928, stated that about three years after the operation she moved to the Middle West and that he had not been able to get in touch with her since, but up until that time she had been in perfect health.

FIG. 2.—Cut-section of Unilateral Polycystic Kidney removed by nephrectomy.

DOCTOR THOMAS remarked that polycystic kidneys are, perhaps, the most interesting of all the anomalies of the kidney. Naumann found sixteen cases in 10,177 post-mortem examinations, of which fourteen were bilateral. Sieber collected 244 cases from the literature and stated that the bilateral cases outnumbered the unilateral cases ten to one. It is interesting to note that in Sieber's nine unilateral cases, six were on the left side, which is declared to be the more common in the unilateral cases.

Recently he had a case on his service at the Graduate Hospital: a unilateral polycystic kidney, discovered at autopsy, which was on the left side; also, the case which is reported tonight was on the left side.

Females predominate in the analysis of sex. Apparently there is a marked predisposition for the disease to appear in families, and it has been reported in more than one generation. Osler refers to a mother with five children, all with polycystic kidneys. Ball reports polycystic kidneys in three generations. Rochert reports, in the attempt to cross St. Bernard dogs with bassets, both ways, all the pups died within a week after birth and were found to have polycystic kidneys. This was thought to be due to failure of the two systems, from which the kidney is formed embryologically, to unite.

Nothing new has been added in the last few years with regard to the pathogenesis in such cases, although while there is general acceptance of the theory of the failure of the two embryological structures to unite, still it has been reported by several workers that dye injected into the ureter has appeared in the kidney showing that there is a direct communication. There are often many associated lesions such as hypertrophy of the heart, arteriosclerosis,

cysts of the liver, and often many other congenital lesions, occurring in the same case. While the cysts occur from birth to the eightieth year, the greatest incidence is usually from forty to sixty years, and the clinical picture is often divided into: (1) Progressive enlargement; (2) the presence of a tumor together with subjective pain such as hematuria, pyuria, etc.; (3) uremia.

The duration, after symptoms have developed, is anywhere from ten to twenty years. The average course is not more than five to six years. According to Goinet and Rabaud death occurs immediately in 50 per cent. of the cases. Nephrectomy is usually employed only as a last resort because most cases are bilateral and the mortality has been exceedingly high. Deaver states that it is not enough to go by the palpating hand to be assured that the other kidney is not polycystic, because in four such cases in which he did nephrectomy, when the other kidney to a palpating hand did not reveal any cysts, three died within three years of polycystic degeneration of the other kidney.

Morris reports that out of five nephrectomies for polycystic kidneys two were living and well three years and seven years, respectively, after the operation; two died within a few days, while one lived a few weeks. Torrence: one living and well two years after operation. Albarran and Imbert report twenty-five operative recoveries in thirty-four cases, in which fifteen of the patients survived from several weeks to seven years afterward; six had probable recurrence in the remaining kidney, two to three years after operation.

Sieber, in sixty-two operative cases, reported a mortality of 33 per cent. and rapid recurrence in ten cases, the remainder being well eight months to seven years after operation. Brin reported nephrectomy in seventeen cases, and Blatt, in nine cases. In twenty-two cases of nephrotomy and nephrectomy the mortality was 31.8 per cent., and only two patients were alive after two years. Employing the Rovsing operation, Brin reported sixteen cases with four operative mortalities, or 25 per cent. The Mayos report fourteen nephrectomies with one operative death, one died of pelvic malignancy very shortly afterward, nine were living and well from, two at two years up to one at ten years. Employing the Rovsing operation in ten cases, seven of which were diagnosed before operation, two died following the operation and one lived for three years, four were living at one year, one at two years, one at three years, and one at five years.

In the case now reported the cysts were confined mostly to the lower two-thirds of the kidney and, perhaps, this has something to do with the fact that it was unilateral and that at least for three years, if no longer, the patient remained free of symptoms on the other side.

Dr. Charles F. Nassau said that he had operated upon but one patient with a right-sided unilateral polycystic kidney. After exposing the kidney he recognized the condition and in order to determine the condition of the left kidney he opened the peritoneum and palpated the other kidney, which was apparently normal. The entire right kidney was involved as in the congenital condition. The woman recovered and is perfectly well as far as is known.

These lesions must be rare because in the course of years the speaker has had a good many kidney cases and this is the only instance he remembers of true polycystic kidney.

Dr. George Outerbridge spoke of the Rovsing operation, in which he was interested because of a case recently under his care, of a colored woman who was referred to the hospital with the diagnosis of large ovarian cysts. The abdomen was markedly distended, with irregular cystic masses, which on superficial examination certainly suggested that diagnosis. However, from pyelograms it was diagnosed definitely as bilateral polycystic kidney, but as the masses were so large and apparently multiple, he thought it justifiable to make a small exploratory abdominal incision to be certain that he was not dealing with a combination of the two conditions, and that some of the cysts might be ovarian and therefore removable. This, however, was found not to be the case, the cystic masses being entirely renal, the left kidney being almost the size of a small football and the right somewhat smaller, but still very greatly enlarged, and cystic. He did not wish to puncture any of these cysts through the peritoneal cavity, and as any thought of removal was entirely out of the question, the abdomen was closed and nothing further done. It would seem, however, that this might possibly be a suitable case for the Rovsing operation.

## X-RAY DESTRUCTION OF KIDNEY

Dr. Alexander Randall presented a man who entered the University Hospital in May, 1925, with acute appendicitis. An appendectomy was done by Dr. I. S. Ravdin and, though convalescence was complicated by lobar pneumonia, he made a complete recovery during the next two years. During these two years he had, at times, pains of dull character in the lower abdomen to the right of the mid-line, and referred to the pelvis. There were no acute symptoms and the patient attributed his discomfort to bowel irregularity. There were no urinary symptoms.

He was re-admitted to the University Hospital two years later, in April, 1927, because of his lower abdominal discomfort. X-ray was negative for calculus. The urine showed white blood cells and red blood cells but was negative for the tubercle bacillus, and a pure culture of non-hemolytic staphylococcus was found. His condition was felt to be pyelitis and he was sent back to his family physician with advice.

The pain in the lower abdomen continuing, he was again admitted to the hospital a year later (March, 1928). His pain now was continuous and at times sharper and cramp-like. Hæmaturia had been noted on two occasions during the past year, though his major complaint was lower abdominal pain and considerable digestive disturbance, flatulence, cardiac palpitation, dragging weight in abdomen, though no nausea or vomiting, and no bladder discomfort. An operation was performed by Dr. George P. Muller, under a tentative diagnosis of post-operative adhesions, on March 17, 1928. The peritoneal cavity was found to be normal. In the right iliac fossa a hard calcareous mass was felt behind the posterior peritoneum. Incision over it, with the expectation of removing a calcified retroperitoneal lymph gland, delivered a ureteral calculus. The ureter being opened, drainage was established by placing a tube retroperitoneally, giving it an exit through a second-

ary incision directly medial to the anterior superior iliac spine. Further examination revealed the right kidney lying directly under McBurney's point, markedly ptosed, but fixed in that position. Four weeks later he was discharged with a patent urinary fistula to regain some strength before nephrectomy was done.

He was re-admitted to the hospital in May, 1928, and pyelographic studies confirmed the suspicion of ectopic right kidney, and on May 10, 1928, Doctor Muller performed a right nephrectomy extraperitoneally. The organ was tightly adherent and very difficult to mobilize. It was removed in three portions and all major vessels doubly ligated. Gauze drainage was instituted. Forty-eight hours later a transfusion was given and the same repeated three days subsequently. He was discharged convalescent four weeks later with a wound healed to a small sinus that continued to discharge.

The patient was re-admitted in November, 1928, on account of the persistent urinary fistula. Various cystoscopic and pyelographic studies established the fact that there was no connection between the bladder and the fistula; that there was a normally developed and functioning left kidney and ureter and allowed of but one conclusion, *i.e.*, the persistence of some portion of the ectopic kidney still viable and functioning through the persistent fistula. Indigocarmin administered intravenously, while showing prompt and normal elimination per bladder from the left kidney appeared as the faintest tinge of color from the fistula, and the same result was obtained with repeated phenolsulphonephthalein tests.

Discussion centred on the relief of this distressing condition without subjecting the patient to further operative measures, and recalling the work of Hartman and his associates in producing marked interstitial nephrosis in experimental animals by X-ray, it was felt that the remnant of this ectopic kidney might likewise be destroyed by radiation. Hartman's efforts were to produce chronic interstitial nephritis in animals for experimental purposes, which he unquestionably accomplished to the point of producing uræmia and death, but he does not hint at the possibility of this pseudosurgical use of the measure. November 22, 1928, this patient received his first treatment and was given five daily exposures of thirty minutes each. The day following his first exposure the drainage was definitely increased and on the next day there was almost no drainage at all. He was discharged on the last day of treatment, November 27, 1928, with unquestionably reduced drainage. Returning January 8, 1929, he reported but little change in the amount and was given five further exposures, ending January 15, each of thirty minutes' duration. Feeling that the failure of the first series was due to the too limited application, this second series of exposures were given to cover a greater area. It was not until after beginning the above X-ray treatment that justification for the same was found in the recently published article by Kline, who reports four cases of post-operative ureteral fistulization in each of which the kidney involved was caused to cease secreting by X-ray destruction.

Dr. Thomas C. Stellwagen asked if smears were made from the sinus and analysis made of the discharge. He has had occasion to treat three such cases. One patient had had a stone removed from the kidney. He had a stone-forming kidney and also had an obstruction further down in the ureter and would not submit to further surgery when the condition returned. At present this man is perfectly well because his sinus is closed. Finally, after numerous X-ray exposures the kidney ceased functioning, but whether or not

the kidney is absolutely out of commission is uncertain. He submitted to only one cystoscopy which showed the kidney was not functioning at all. This case is one which is comparable to the case shown by Doctor Randall, that the kidney ceased to function following X-ray.

Dr. Alexander Randall said that Doctor Stellwagen raised the question as to whether the urine from the sinus had been analyzed. With the patient in a certain position he was able to collect two-thirds of a test tube of fluid from his fistula in three-quarters of an hour's time. Analysis showed the usual urinary salts present though in very low concentration. The same was true of both the indigocarmin and the phenolsulphonephthalein dye tests, the amount obtained being too low for estimation.

In regard to the work which Hartman and his co-workers have done at the Ford Hospital, it is of interest to point out that they were able to cause such a high grade of experimental nephritis as to produce coma and death from typical uræmic symptoms (including blood studies) in their experimental animals. They were interested only in this side of the question and have not considered its surgical application. Kline, on the other hand, has reported four cases of ureteral fistula following Wertheim hysterectomies, and in each case was able to put the involved kidney completely out of function by X-ray exposure. Apparently in two of his cases the involved kidney was of equal function to that of its mate before X-ray treatment was instituted. Doctor Randall stated that his is but a preliminary report, and he hoped at a later date to be able to report the case as a permanent cure.

## NEW GROWTHS OF THE RENAL PELVIS

Dr. Leon Herman and Dr. Lloyd B. Greene (by invitation) read a paper with the above title for which see page 682.

Dr. John T. Bauer remarked that the first case mentioned by the essayists appeared to be histologically a papilloma of low-grade malignancy. The second case which Doctor Herman thought to be a flat carcinoma is quite malignant, infiltrating the parenchyma of the kidney, and vaguely suggests a papillomatous origin. The other cases which were examined involved the pelvis and did not extend into the renal tissue.

In regard to malignancy the papillomata of the renal pelvis are similar to those of the bladder, that is, they may appear histologically benign and be clinically malignant. The delicate character of the fronds, the ease with which they break and may become implanted in the ureter and bladder may explain this malignant tendency. It is interesting to comment upon the early symptom of hæmorrhage in these cases. This may be due to the rupture of the vessels in the delicate fibrous trabeculæ when the papillary tips are broken.

Dr. Paul A. Bishop said that coöperation between the urologist and the röntgenologist was essential when interpreting films in these cases. There are so many things that these defects and distortions of the pelvis can be due to. The presence of a circumscribed defect in the kidney pelvis is not

enough to diagnose papilloma. A stone which is non-opaque or a blood clot, which is likely to occur in these cases, may also stimulate this appearance, but a localized distortion of a calix or two calices and a filling defect at the base of it are suspicious even from the pyelogram alone. The speaker has suggested that Doctor Herman try flattening the kidney pelvis by using pressure before the medium is injected, as he is sure it will improve the results from pyelography.

Dr. B. A. Thomas said that pyelography of the kidney pelvis is one of the, if not the most, interesting fields in urological diagnosis. Contrary to the infallibility of pyelography in the diagnosis of papillary tumors of the kidney as stressed by Doctor Herman and Doctor Greene, they have shown by the citation of cases in their own paper, at least by one of them, that it is impossible to differentiate between certain solid and papillary tumors. All know that in the majority of cases a filling defect of the renal pelvis is diagnostic of a papillary growth. Characteristic though it may be, it is not, however, infallible.

In a case which came under the speaker's observation and was operated recently, and which was included in Doctor Herman's and Doctor Greene's presentation, the pyelogram showed a definite filling defect of the lower calix of the renal pelvis, characteristic of papilloma, but at operation a large hypernephroma occupying the lower pole of the kidney was removed. The calix had not filled fully owing to compression by proliferation of hypernephromatous growth. Also, within the past year, he has seen two patients thought by pyelography to have papillomata of the kidney pelvis or calices, but at operation calculi were found and had doubtless caused the filling defects. Therefore, one must not be too dogmatic or arbitrary concerning the interpretation of renal pelvic filling defects. In the future it may be possible to differentiate unerringly in the pyelograms of kidney tumors—the solid from the papillary—but today one cannot be too sure with respect to this differential diagnosis.

Doctor Thomas did not quite agree with Doctor Herman in regard to indigocarmin in tuberculosis of the kidney. His experience has been that it has been well nigh infallible, and the best aid at our command in the diagnostic management of these cases; moreover, it has served admirably in differentiating between those cases that should be treated medically and those wherein surgical treatment is indicated. In his experience surgery has been confined to those cases in which there was delayed elimination of the dye beyond the normal time limit, or none at all. Regarding the case of carcinoma of the ureter he understood Doctor Herman to say that the dye was eliminated in twenty-five minutes from the right kidney and in sixteen minutes from the left or affected side. Apparently there was no involvement of the kidney whatever—the lesion, a carcinoma, was confined to the ureter. Seemingly, there was no obstruction of the ureter on that side and, therefore, no interference with the elimination of urine from that kidney. He did not see,

therefore, why any interference with the function of that kidney should have been suspected.

Dr. Lloyd B. Greene said that there is a fairly characteristic pyelogram in papilloma of the renal pelvis. There are certain factors that make the diagnosis speculative. The most common are blood clots and stone, but by repeated examination these may be eliminated as a source of error. Since pyelography is being done so much more frequently now than even a few years ago and the specialty of urology is advancing so rapidly a positive diagnosis will probably be the rule rather than the exception in the future.

Dr. George P. Muller said that Doctor Herman referred to the case which Doctor Bothe will report in detail. The patient was fifty years of age, had no symptoms until August, 1928, when he had an attack of acute bladder pain, passed more clots, at which time he came under our observation. Doctor Bothe made a pyelogram and diagnosed papilloma of the pelvis of the kidney. Nephrectomy was performed. When the pelvis was exposed it was felt to contain a growth about the size of a walnut. Perhaps he should have opened the pelvis of the kidney, and if it were found benign, have snared the base, but Doctor Bothe and the speaker felt it was a malignant condition and that a nephrectomy had better be done. The man was well when last heard from, one week ago.

Dr. Thomas G. Stellwagen said that Doctor Herman almost persuades him to believe that the diagnosis of tumor of the pelvis of the kidney can be made by pyelogram. The speaker felt, however, that in the vast majority of cases it was guessing. Doctor Stellwagen has had a fair number of cases of papilloma and has been able to diagnose a few of them. Some, which were diagnosed as papilloma, turned out to be hypernephroma, some to be stone, and so it went. He ran the gamut of the usual misinterpretation of pyelograms. He makes it a matter of routine to radiate these patients previous to operation and then again after operation. The speaker recalled definitely three cases of malignant growths of the kidney which are well and alive today. One of whom he saw recently has gained twenty-two pounds in weight and has had no symptoms whatever.

Dr. Astley P. C. Ashhurst asked whether it is common to have profuse hæmorrhage in growths of the renal pelvis which are only microscopical in size. He had a patient with hæmaturia, in whom the pyelograms were practically negative, and at operation removed what seemed to be a normal kidney, on the assumption that a small tumor was bleeding into the pelvis. The pathologist, Dr. C. Y. White, examined the specimen very carefully, but only after cutting it up into mincemeat did he finally find an area which he thought looked abnormal. On microscopical examination he found this was a hypernephroma bordering on the pelvis. The patient has been entirely free from hæmaturia since the operation.

Dr. Henry P. Brown, Jr., recalled a case in the service of the late Dr. Robert LeConte in which the diagnosis was essential hæmaturia. On

account of persistent bleeding Doctor LeConte decided upon nephrectomy. Section of kidney revealed, in the upper pole of the cortex, an area approximately five millimetres in diameter, which under the microscope proved to be early tubular carcinoma.

Dr. Leon Herman, replying to Doctor Ashhurst's question, said that massive hæmaturia from a hypernephroma of microscopic size would seem to be unlikely, and yet considerable renal bleeding occurs not infrequently in the absence of adequate demonstrable cause. In many instances we are compelled in the absence of demonstrable pathology, to classify these cases as idiopathic or essential hæmaturia. This is a hazardous diagnosis, but a necessary one in some instances. It should always be a tentative one, however, and adhered to only as long as repeated examinations fail to disclose a real pathological cause of bleeding. Excessive hæmaturia may necessitate nephrectomy in a few of these cases.

The diagnosis of intrapelvic tumors is difficult, but the speaker cannot agree with Doctor Stellwagen and Doctor Thomas that pyelography is of little or no aid. The pictures which we have shown were of great assistance and, as experience grows, we will be able, no doubt, to standardize the defects produced by these tumors just as we have been able to do with the more common lesion of the kidney. A normal pyelogram of the bleeding kidney does not remove the possibility of an early neoplasm.

## SCROTAL DRESSING

Dr. Thomas Stellwagen said that for some years past he had been evolving a surgical dressing for the scrotum and felt that it was sufficiently perfected to offer it to the profession. It eliminates many of the inconveniences formerly encountered. It is readily applied and stays where put when properly constructed. Further, it permits evacuation of the bowels without disturbing the dressings and makes possible the use of the enæma or colonic tube for irrigation without soiling of the operative area. In the past he has used the perineal "T" binder and the crossed spica of the perineum. The binder was unsatisfactory as it did not give the proper support to the scrotum. In the post-operative tossing of the patient, it frequently became displaced and permitted exposure of the operative field. It also necessitated removal of the dressings when the toilet was attended to, etc. The crossed spica is an excellent dressing, but difficult to apply and frequently uncomfortable. To put it on properly the patient must be raised in bed upon an elevator. This is uncomfortable and often distressing. Again, whenever the case is dressed the entire procedure of application of a new bandage must be gone through with. The scrotal sling that the speaker described obviates these difficulties.

It consists of a bridge of adhesive plaster, sometimes spoken of as a "Bellevue bridge", with modifications and additions as shown in the diagrams. Before applying the sling or bridge, the anterior surfaces of the thighs should be cleanly shaved and wiped with sponges saturated with ether to

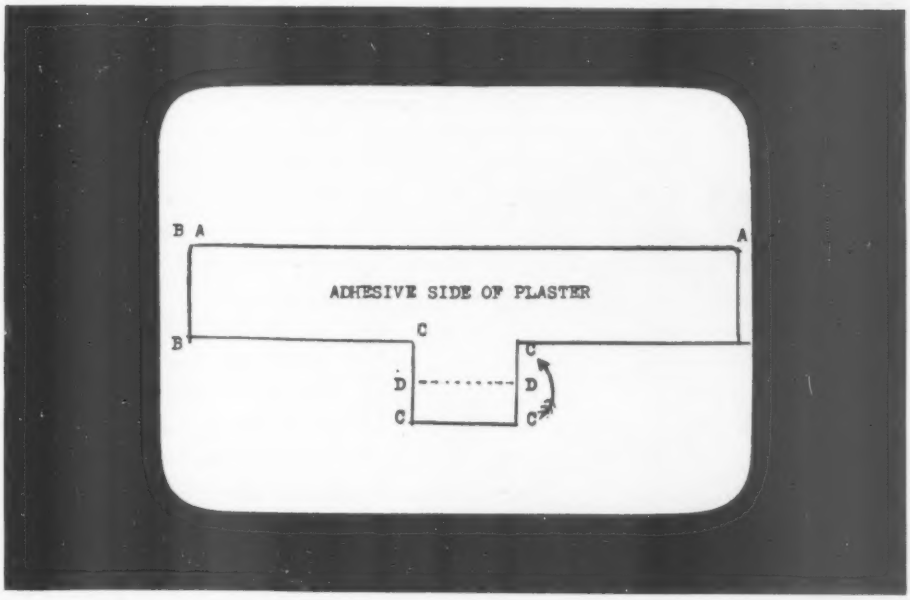


FIG. 1.—Pattern as cut from the adhesive plaster roll. Measure the distance from the outer side of each thigh with patient on back and legs in a comfortable position. Length of the scrotum should be allowed for. A-A thigh distance; B-B the scrotal length; C-C-C-C lip to be folded upon itself along D-D.

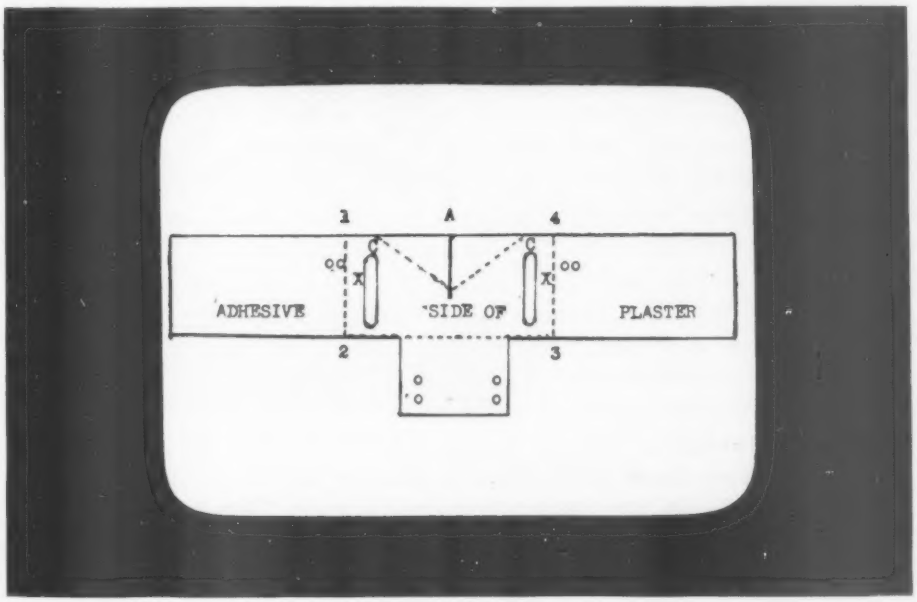


FIG. 2.—Stages in the preparation of the dressing.

facilitate adhesion of the plaster to the skin. It is further important to use fresh adhesive plaster to insure good retention of the dressing.

A straight cut is made from one-third to one-half of the width of the bridge at the line A-A. The two triangular corners, A-A-C, are then turned down on the adhesive side and pressed fast. This forms a notch for the perineo-scrotal junction, thus making a close fit to the perineum which is very essential. The next step is to cut two spreaders from wood tongue depressors and press them fast to the adhesive surface at X and X. These keep the dressing well stretched and prevent subsequent wrinkling. The area within the figures 1, 2, 3, 4, is then covered, sticky side to sticky side with adhesive plaster and ironed down tight over the spreaders. It is notched out at the perineo-scrotal point to conform to the pattern. Double holes are then snipped by curved scissors at the points marked oo and tapes of proper length are tied into them.

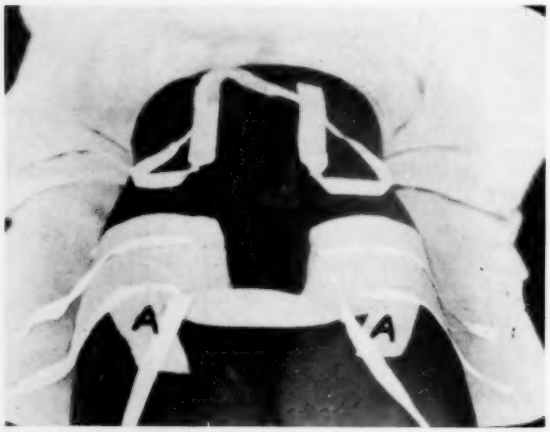


FIG. 3.—The bridge applied; A-A strips of adhesive plaster used to tack down the lower angles of the plaster. The tension of the tapes when tied over the gauze dressings tends to raise these angles.

The dressing is best applied as follows: The scrotum is raised upward and backward upon the abdomen as far as possible. While in this position the bridge is applied, making sure to get the perineo-scrotal-notched area snugly intact with the perineum. In this position the thigh flaps are then applied with proper tension on this bridge. The final step in the dressing is to use a fairly large piece of rubber dam with a hole for the penis to project through. This largely prevents soiling of the dressings by urine.

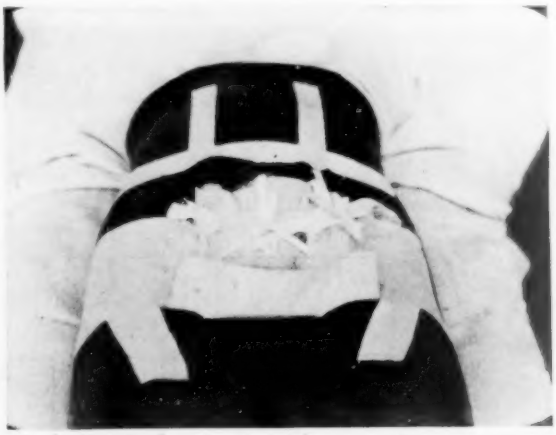

FIG. 4.—Dressing in place.

# BOOK REVIEWS

I. SURGERY IN THE TROPICS, by SIR FRANK POWELL CONNOR. Sm. oct., cloth; pp. 293. Philadelphia, P. Blakiston Son & Co., 1929.

Here is a little book from the professor of surgery in the Medical College of Bengal. It is attractive in its make-up and convenient in its form, not too big to be slipped into one's pocket, or to be thrown into one's kit bag. It is true that many of the subjects of which it treats can rarely come into the experience of a surgeon practicing in a temperate climate, nevertheless, it is quite evident that in the future, the rapid overcoming of the bar of distance in separating mankind will make the diseases peculiar to the tropics to come much more frequently within the scope of the practice of the temperate zones. This book of Connor does not pretend to be a textbook of tropical medicine nor a treatise on general surgery, but confines itself to those special aspects of surgery and surgical diseases which are peculiar to the tropics. To this field the author has confined himself with admirable discretion. The manner in which he has treated his subject is peculiarly engaging. One feels, as he turns its leaves and reads its paragraphs, that he is talking with a man who is relating to him what he himself has seen and describing things with which he is personally familiar. There is a certain chumminess, if I may be permitted the term, about the book which makes its reading especially interesting. We note the claim that although the conditions of life in the tropics, including, as they so often do, heat, dust, dirt, and uncleanly habits, provide peculiar opportunities for septic infection, nevertheless, in spite of these difficulties, the practice of surgery has been raised by tropical surgeons to almost as high a degree of perfection as in western countries.

The author begins with staphylococcic infections. No one who has spent any time in tropical regions will dispute the importance and prevalence of such infections, though in their simple elements comparatively slight, yet in their diffusion sources of great annoyance and even of danger to life. Speaking of boils, we can imagine our New York colleague, Theodore Dunham, who, in 1919, described before the New York Surgical Society an original method of treating boils by perforating the focus of each boil by the eye-end of a needle dipped in carbolic acid, reading now, ten years later, the statement of an East Indian surgeon that a very efficient method of treatment of boils is "the drilling of each boil by the sharpened end of a match or probe of ivory dipped into pure carbolic acid". It is to be hoped that there will not arise any ill-natured discussion as to priority in the matter!

One cannot but be interested in the statement that tuberculosis is one of the commonest diseases in the tropics and gives rise to an enormous mortality. This, the author thinks, can be explained largely by insanitary surroundings and lowered resistance due to heat, acting with many special causes. As to

syphilis, the author draws attention to the enormous incidence of the disease in the tropics but does not enter into any extended discussion. More room is given to the discussion of that closely related disease, frambœsia or yaws. We are assured that, although the organism which produces yaws is morphologically indistinguishable from that of syphilis and that the Wassermann reaction is positive in both diseases, their differential diagnosis is not difficult. Yaws is a less serious disease than syphilis and is much more amenable to treatment. Although mercury is ineffective against yaws, the salvarsan derivatives and bismuth preparations are very useful. The various granulomata, actinomycosis, Madura foot, mossy foot, and blastomycosis are mentioned more or less fully. The surgical aspects of the dysenteries receive the largest share of attention of any one subject in the book. Amœbic dysentery, the dysenteries caused by the bacillus of Shiga and of Flexner and that due to Bilharzia infection are each quite fully discussed, including necessarily the subject of amœbic hepatitis and liver abscess. Then comes the engrossing subject of filariasis. The filariæ of Bancroft are responsible, the author states, for surgical lesions, the multiplicity and importance of which can hardly be exaggerated. What malaria means to the tropical side of medicine, filaria means to the surgical side, being comparable with spyhilis as regards its widespread incidence and the variety of infections produced. Here are introduced the numerous complications of diseases of the lymphatic system with chylous effusions into serous cavities and elephantiasis of various portions of the body whose lymphatic circulation becomes obstructed. Various affections due to parasitic insects, intestinal parasites and snake-bites close the volume.

That which gives the greatest interest to the book is the colloquial style in which it is written, and as one closes the volume and lays it down, one has the sensation of having spent the evening in talk with one who has had a personal knowledge of the things he has been talking about and who knows how to talk about them in an interesting and instructive manner.

II. The Mobilization of Ankylosed Joints by Arthroplasty. By W. Russell Macausland, M.D., and Andrew R. Macausland, M.D., oct.; cloth; pp. 252. Philadelphia, Lea and Febiger, 1929.

Operations for the purpose of restoring mobility to ankylosed joints belong to the new school of orthopedic surgery and are among its most important and finest achievements. Yet one reads with interest of the operations of Barton, in Philadelphia, as long ago as 1826 for the relief of an ankylosis of the hip-joint, in which an osteotomy through the great trochanter and part of the femoral neck was done. The subsequent manipulations were successful in preventing recurrence of the ankylosis for two years when it recurred. Rodgers, of New York, in 1840 improved Barton's method by removing a disc of bone from between the trochanters with the result of securing permanent mobility to the joint. Reports of occasional efforts of this kind for restoring mobility to ankylosed joints by the Rodgers' method appear from time to time from the first effort of these earlier surgeons mentioned to the

period of the introduction of antiseptic methods into surgery, culminating in the well-known treatise of Ollier on "Resections and Conservative Operations on Bones" in 1885.

This book by the Boston surgeons presents to us an excellent study of the general subject of ankylosis of joints and the possibility of relief by arthroplasty as developed and perfected to present time by the efforts of the surgeons of all countries. The reviewer remembers with pleasure the enthusiasm of the lamented Murphy of Chicago in this line of work and particularly the results obtained by him in arthroplasty of the hip-joint. It is pleasant to see that the authors of the work under review give proper credit to the Chicago surgeon for his masterly labors in this field.

The authors do not claim that arthroplasty can restore a joint to its normal condition. The most they claim is that in many cases "it creates an articulation that is as satisfactory from the point of view of service and function as is the normal joint. The new joint has stability; it is strong; it adapts itself to weight-bearing and its nicety of motion makes the limb a functional and serviceable member." Such is the claim of the authors. The reviewer, however, is inclined to think that such a claim is a little too enthusiastic and that rarely is the ultimate result secured by arthroplasty which fulfils all these claims, although a fairly satisfactory joint is often secured; one that is an immense improvement over the disabling ankylosis previously existing.

Each joint in succession is taken up for consideration and detailed methods of mobilizing procedures are described and abundantly illustrated. The book as a whole is an extremely practical one and may be accepted as an authoritative statement of the present condition of the surgery of ankylosed joints.

DISEASES OF THE THYROID GLAND. By ARTHUR E. HERTZLER, M.D. Second edition; large octavo; cloth; pp. 286. St. Louis, The C. V. Mosby Company, 1929.

The author published the first edition of this book in 1922 as a contribution giving the result of observations and studies in a small country hospital somewhat isolated and providing material which could be followed up in a large proportion of cases to their end results. The author then stated that the study of his cases had convinced him that statistics hitherto published were of little value. They presented the disease in too optimistic a light and a great overestimate of the permanent value of any treatment. He now presents this new edition as a continuation of the studies contained in the previous one. Many of his patients he has been able to follow for more than thirty years and is able to present conclusions arrived at that are of value, arrived at only after constant comparison of clinical pictures and pathology ascertained by repeated examinations in after years.

The text is very excellently illustrated by a large number of cuts, one hundred and fifty-nine in all. In the book itself, a consideration of the normal morphology of the thyroid gland is followed by a full discussion of the pathological anatomy of tumors of the thyroid gland. This chapter on pathol-

ogy occupies more than one third of the pages of the book. It is well written; its teachings are clear and as a whole, it is an excellent résumé of present knowledge of the pathology of the various tumors of the thyroid gland.

The matters of symptomatology and diagnosis receive due attention. The pages devoted to goitres in unusual places are especially instructive. A chapter on hospital management of goitre patients is contributed by Dr. Victor E. Chesky. The last fifty pages of the book are taken up with the consideration of operative attacks upon the gland. The text here is especially well illustrated. One is impressed, however, with the feeling that the author does not err on the side of being too conservative in his work. The possibilities of injury to the recurrent laryngeal nerve or the removal of parathyroid bodies receives mention but with a lack of emphasis that hardly comports with the importance of the injuries or the real difficulties with which, in many cases, such injuries are avoided. Myxedema caused by removal of too much thyroid tissue receives brief mention qualified by the rather emphatic statement that "it has been repeatedly proved that only a small amount of thyroid tissue with sufficient blood and nerve supply is adequate to carry on normal function of the gland." One would like to have had the opinion of the author with his large experience as to just how much thyroid tissue the less experienced surgeon should plan to leave behind him in any operation upon the thyroid gland. The book, as a whole, is an excellent, practical treatise upon the subject to which it is devoted.

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**EDITORIAL ADDRESS**

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